



# JOURNAL OF AGRICULTURAL RESEARCH

VOL. XIX    WASHINGTON, D. C., SEPTEMBER 1, 1920    NO. 11

## GENETICS OF RUST RESISTANCE IN CROSSES OF VARIETIES OF TRITICUM VULGARE WITH VARIETIES OF T. DURUM AND T. DICOCUM<sup>1</sup>

By H. K. HAYES, *Head of Section of Plant Breeding, Division of Agronomy and Farm Management, Department of Agriculture, University of Minnesota*, JOHN H. PARKER, *Scientific Assistant*, and CARL KURTZWEL,<sup>2</sup> *Assistant Pathologist, Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture*

### INTRODUCTION

The black stemrust (*Puccinia graminis*) of small grains causes enormous losses. Reduction in yield of from 10 to 50 per cent of the wheat crop is common. At irregular intervals the black stemrust of wheat causes almost complete failure, especially in the spring-wheat area of the upper Mississippi Valley. Control of this disease, which develops into such terrific epidemics, is impossible by any method now available to the individual grower. For this reason the development of resistant varieties assumes great importance. While the barberry eradication campaign now being carried on over a wide area will certainly reduce the amount of rust, local outbreaks may perhaps be expected even after barberries have apparently been eradicated. The attempt to develop resistant varieties, therefore, should continue. There is every reason to hope that the stemrust problem can be solved by barberry eradication and the development of resistant wheat varieties.

When the present study was outlined, the evidence seemed to show that parasitic action of the rust was constant. Recent extensive studies (22, 23)<sup>3</sup> have confirmed this view and indicate that the bridging hypothesis (11), which was supposed to account for the increase or decrease in

<sup>1</sup> Published with the approval of the Director as Paper 187, Journal Series, Minnesota Agricultural Experiment Station. Cooperative investigation between the Minnesota Agricultural Experiment Station and the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture.

<sup>2</sup> The breeding of spring wheat for rust resistance was begun by Dr. E. M. Freeman and E. C. Johnson in 1908 and has been continued without interruption until the present time. The present cooperative arrangement between the Division of Plant Pathology and Botany and the Section of Plant Breeding, Division of Agronomy and Farm Management, of the University of Minnesota, was made in the spring of 1916. The writers wish to acknowledge the helpful cooperation of Dr. E. M. Freeman and Dr. E. C. Stakman in this investigation.

<sup>3</sup> Reference is made by number (italic) to "Literature cited," pp. 541-542.

virulence of the rust, is probably incorrect. More recent investigations of the wheatrust fungus have shown that there are numerous biologic forms (25) which can be differentiated only by their action on various pure-line wheat varieties. This is a very serious obstacle to the production of rust-resistant varieties by breeding, although the fact that Khapli (C I 4013),<sup>1</sup> an emmer imported from India, is resistant to all biologic forms so far isolated shows that the problem is not entirely hopeless.

Former breeding investigations have determined which varieties of wheat are commonly resistant to stemrust at University Farm, St. Paul, and have also indicated the behavior of rust resistance in crosses. In the light of this information it was decided to make a careful genetic study of one or two crosses, hoping thus to solve the plant-breeding phase of the rust-resistance problem. The second generation of the crosses reported in this paper had already been studied before it was known that there were sometimes numerous biologic forms of the rust in the same locality. It seemed worth while to complete the study of inheritance of rust resistance in these crosses by growing a small  $F_2$  family of each  $F_2$  plant which produced viable seed. All barberry bushes were removed from the immediate vicinity of the rust plot early in the spring of 1918, and the artificially induced epidemic was produced with a known racial strain of the biologic form *Puccinia graminis tritici* Erikss. and Henn. Therefore, the greater part, if not all, of the rust infection present during the season of 1918 was due to this one biologic form. One uredinium found on Kanred (C I 5146), which is known to be resistant to the strain which was used to induce the epidemic, proved to belong to another biologic form.

The present paper is a report of the inheritance of rust resistance in its correlation with botanical and morphological characters of crosses between *Triticum vulgare* with varieties of *T. durum* and *T. dicoccum*.

#### SOME PREVIOUS CROSSES OF WHEAT SPECIES

Because of the many differential characters and the great economic importance of the crop, wheat has been frequently used in studies of the laws of inheritance. Vilmorin (26, 27) reported quite extensive tests of crosses between *Triticum sativum* L., *T. turgidum*, *T. durum* Desf., *T. polonicum* L., and *T. spelta*. From the Mendelian standpoint the results obtained are interesting. He observed remarkable uniformity in the  $F_1$  generation, wide diversity in the  $F_2$  generation, and states that the predominating force after the  $F_3$  generation is that of heredity, which compels the plants to reproduce their characters in their immediate descendants. Vilmorin placed spelt and common wheats in one group and poulard and durum in another, because he found that either spelt or common crossed with poulard or durum produced all four types in the

<sup>1</sup> Cereal investigations number.

segregating generations. These types were easily fixed after several years of selection. The four types were believed to have a common ancestry and to belong to one botanical species. Unsuccessful attempts were made to cross these species with *T. monococcum* L. This led Vilmorin to conclude that *T. monococcum* belonged to a separate species.

Tschermak (25) confirmed Vilmorin's conclusions regarding the production of common, durum, spelt, and poulard forms from crosses when the groups differed in the solid and hollow stem character. He stated that the polonicum type was obtained only when it was used as one of the parents. Relationships were illustrated on a factor hypothesis by assuming (1) that *Triticum polonicum* contained two dominant factors, (2) that common wheat lacked these factors, and (3) that durum contained one of these factors but not the other. Tschermak also thinks that *T. monococcum* is different from other wheat species. He obtained hybrids between *T. monococcum* and *T. vulgare* and one  $F_2$  plant, which soon died.

Blaringhem (6), however, succeeded in crossing *Triticum durum* and *T. polonicum* with *T. monococcum*. Sterility was at first of frequent occurrence in these crosses, but in later generations it was much less common.

Explorations by Aaronsohn in 1906 (1) confirm the experimental evidence cited above. A wild emmer, *Triticum dicoccum dicoccoides*,<sup>1</sup> found in 1906, is interesting because it tends to confirm the report that such an emmer was collected as early as 1885.

Crosses between Black Winter emmer and Fultzo-Mediterranean (15) had strongly keeled glumes with hard, adherent chaff in the  $F_1$  generation. The  $F_2$  plants varied widely in type and exhibited transgressive segregation for some characters. There was considerable sterility in this cross. The hairy chaff and black color of the emmer parent were linked in inheritance.

Freeman (12) found evidence of linkage between high ratio of width to thickness of head and hardness of grain in a cross between durum wheat and a variety of bread wheat. The bread wheat parent had a square head with soft, opaque grains, while the durum parent had a much flattened head and produced hard, translucent grains.

In a recent article on heredity of quantitative characters in wheat (13) a cross between durum and common wheat is reported. It gave normally vigorous plants in the  $F_1$  generation. In the  $F_2$  generation, however, many seeds failed to germinate; and among those with a normal vegetative development were found plants exhibiting every degree of sterility, from perfectly sterile to fertile plants.

Linkage has been reported by Engledow and Biffen in crosses between Rivet, *Triticum turgidum*, and common Pife wheat. Gray glume color

<sup>1</sup> From a cross between durum and common varieties, Love and Craig have produced a form which closely resembles the wild emmer. LOVE, H. H., and CRAIG, W. T. THE SYNTHETIC PRODUCTION OF WILD WHEAT FORMS. *J. Jour. Hered.*, v. 10, no. 2, p. 51-64, illus.

(4) was always found associated with hairy chaff, and partial linkage (10) was found between the factors for black color and the factors for glabrous chaff.

Since sterility has been found by many investigators in wheat crosses and has been confirmed by the results presented in this paper, it seems rather difficult to reach any conclusion regarding linkage, because some combinations may be eliminated.

The inheritance of the principal botanical characters of our cultivated wheats is well known and, therefore, need not be summarized in this paper. The inheritance of beards will be mentioned in connection with our results on sterility. In crosses between the so-called beardless wheats such as Marquis and Bluestem and a bearded variety, the  $F_1$  generation has intermediate awns and in the  $F_2$  generation a 1 to 2 to 1 ratio is obtained. Fully bearded plants breed true in the  $F_3$  generation. Howard and Howard (14) found that there are two classes of wheats with short awns which, when crossed, give fully bearded plants in the  $F_2$  generation and breed true in the  $F_3$  generation. Likewise, crosses between bearded and true beardless forms gave 1 fully bearded plant in the  $F_2$  generation out of 16 plants. The fact of interest for our studies is that fully bearded plants breed true for this character.

#### PREVIOUS STUDIES ON INHERITANCE OF RUST RESISTANCE

The most successful attempt to breed rust-resistant wheats was made by Biffen (2, 3, 5), who found that resistance to striperust (*Puccinia glumarum* Erikss. and Henn.) was a recessive character. Definite segregation occurred in the  $F_2$  generation, and forms bred true in the  $F_3$  generation, the ratio of resistant to susceptible in the segregating families being 1 to 3. From the practical standpoint these experiments have been very valuable. A new variety, Little Joss, was produced, which, because of its rust resistance, yields more on the average than susceptible sorts and has desirable milling characters.

Nilsson-Ehle (20) has likewise made studies of the inheritance of resistance to striperust. Distinct dominance of susceptibility was seldom found. Ordinarily the  $F_1$  generation was intermediate, and in other cases resemblance to one or the other parent was observed. Segregation was obtained in the  $F_2$  generation, but without definite ratios. Transgressive segregation occurred, forms being obtained which were more susceptible than the susceptible parent and others which were more resistant than the resistant parent. The results were explained on the basis of multiple factors.

While many observations have been made on resistance of wheat varieties, the two experiments cited above are the only carefully controlled studies so far reported which show the mode of inheritance.

## METHODS OF STUDYING INHERITANCE OF RUST RESISTANCE

In the studies here recorded crosses were made between Marquis and resistant durum and emmer wheats. Precautions were taken to protect the emasculated heads from foreign pollen. The  $F_1$  plants were grown in individually spaced plots, and seed from each  $F_1$  plant was grown separately. The  $F_2$  families of crosses between the same parent varieties gave similar results and were considered as a single cross. No effort was made with either the  $F_1$  or  $F_2$  plants to protect them from natural crossing, and an error was thus introduced which will be discussed later.

The correlation between resistance in the  $F_1$  and the  $F_2$  generations gave unusual results which indicated that some uncontrolled factor was causing complications. For example, the  $F_1$  cross between emmer and Marquis which was grown in 1916 appeared resistant, while in the  $F_2$  generation which was grown in 1917 the number of resistant plants was much smaller than would be expected if resistance were a dominant character. This led to the belief that very likely more than one biologic form of stemrust was present in 1917.

Each  $F_2$  plant which produced viable seed was tested in 1918. As previously mentioned, the barberry bushes were removed from the immediate vicinity of the rust plot early in the spring of 1918. An epidemic was obtained with a known strain of *Puccinia graminis tritici* which had been cultured in the greenhouse by the Section of Plant Pathology for several generations. This strain had been tested repeatedly on varieties of wheat and proved to be constant.

The 1918 results have been used to determine the resistance or susceptibility of  $F_2$  plants which have been grown the previous season. The  $F_3$  as well as the  $F_2$  data have been used as a basis for placing the  $F_2$  plants in certain botanical groups, for the problem was chiefly to determine the mode of inheritance and correlation of resistance or susceptibility with those botanical characters which are commonly used in differentiating wheat species, some of which are also of economic importance.

## STERILITY IN THE CROSSES OF MARQUIS WITH DURUM AND EMMER VARIETIES

In order to determine whether there is any interrelation between botanical characters and rust resistance, the data for each  $F_2$  plant were taken in a correlated manner. The practical significance is obvious. For example, if durum head and seed characters were rather closely linked with rust resistance in inheritance, it would be necessary to grow a larger  $F_2$  population to obtain the desired form than if each character were inherited independently. In deciding regarding possible linkage it is important to know whether sterility is involved in the crosses.

Sterility might cause the elimination of certain gametic or zygotic combinations, thus actually eliminating the sort desired. Zygotic combinations are sometimes eliminated as is the case with the homozygous yellow mouse combination (7, 17) and with lethal factors in *Drosophila* (19). In some cases gametic combinations are eliminated. Such eliminations occur as a result of pollen or ovule abortion.

#### POLLEN ABORTION

The presence of shriveled or abortive pollen grains is one means of recognizing sterility. The method here used was to shake out pollen from the heads upon a clean glass slide and then place a minute drop of fuchsin on the pollen, then a drop of lactic acid, and a cover glass.<sup>1</sup> By this method pollen was preserved for several weeks and could be studied when it was convenient.

The parent plants and  $F_1$  crosses were grown in 6-inch pots in the greenhouse. A small percentage of small, globular, clear pollen grains were observed. These, together with the occasional shriveled grains, were counted as sterile. The results of these counts are given in Table 1.

TABLE 1.—Counts of sterile pollen grains in wheat species and  $F_1$  crosses between them

|  | Variety.                | Good pollen. | Poor pollen. |
|--|-------------------------|--------------|--------------|
| Parental species:                        |                         |              |              |
| <i>Triticum vulgare</i> .....            | Marquis.....            | 513          | 4            |
| <i>Triticum durum</i> .....              | Mindum.....             | 135          | 2            |
| <i>Triticum durum</i> .....              | Kubanka (C I 2094)..... | 122          | 3            |
| <i>Triticum dicoccum</i> .....           | Emmer (Minn. 1165)..... | 169          | 0            |
| $F_1$ crosses:                           |                         |              |              |
| Marquis $\times$ emmer (Minn. 1165)..... |                         | 475          | 19           |
| Emmer (Minn. 1165) $\times$ Marquis..... |                         | 340          | 37           |
| Kubanka (C I 2094) $\times$ Marquis..... |                         | 113          | 9            |
| Marquis $\times$ Kubanka (C I 2094)..... |                         | 151          | 20           |
| Marquis $\times$ Mindum.....             |                         | 101          | 12           |

These results show that there is a larger percentage of shriveled and abortive grains in the crosses than in the parental varieties. There is also an indication of more pollen abortion in the durum-Marquis crosses than in the cross between emmer and Marquis.

#### COMPARISON OF NUMBER OF SEEDS SET IN $F_1$ GENERATION AND PARENTS

As a further test of sterility, counts were made of the number of barren florets in several  $F_1$  crosses and their parents.

There are two or more flowers in each wheat spikelet, and usually two or three kernels mature. The outer florets of each spikelet are usually most vigorous, and when only two florets per spikelet produce kernels these are usually the outside ones. Therefore, the two outer florets of

<sup>1</sup> Outlined to the writers by Dr. C. O. Rosendahl, Professor of Botany, University of Minnesota.

each spikelet were examined. The result of this examination, together with the percentage of barren florets, is summarized in Table II.

TABLE II.—Number of florets not setting seed in *Triticum vulgare*, *T. durum*, *T. dicoccum*, and  $F_1$  crosses of *T. vulgare* with *T. durum* and *T. dicoccum*

| Variety or cross.                  | Classification.                        | Number of heads. | Number of florets examined. | Number of good seed. | Number of very badly shriveled seed. | Percentage of barren florets. |
|------------------------------------|--|------------------|-----------------------------|----------------------|--------------------------------------|-------------------------------|
| Marquis .....                      | <i>Vulgare</i> .....                   | 15               | 369                         | 341                  | 14                                   | 3.8                           |
| Preston (Minn. 188) .....          | do. ....                               | 17               | 528                         | 500                  | 1                                    | 5.1                           |
| Pioneer .....                      | do. ....                               | 26               | 894                         | 761                  | 1                                    | 5.2                           |
| Average .....                      |  |                  |                             |                      |                                      | 4.7                           |
| D-4 .....                          | <i>Durum</i> .....                     | 16               | 538                         | 499                  | 13                                   | 4.8                           |
| Iumillo (C I 1736) .....           | do. ....                               | 16               | 494                         | 494                  | 1                                    | 5.9                           |
| Kubanka (C I 2094) .....           | do. ....                               | 25               | 898                         | 864                  | 2                                    | 3.6                           |
| Acme .....                         | do. ....                               | 18               | 622                         | 604                  | 0                                    | 2.9                           |
| Average .....                      |  |                  |                             |                      |                                      | 4.3                           |
| Emmer (Minn. 1165) .....           | <i>Dicoccum</i> .....                  | 22               | 630                         | 611                  | 6                                    | 2.1                           |
| Kubanka (C I 2094) × Marquis ..... | <i>Durum</i> × <i>vulgare</i> .....    | 12               | 426                         | 206                  | 9                                    | 49.5                          |
| Acme × Preston .....               | do. ....                               | 3                | 104                         | 62                   | 5                                    | 35.6                          |
| D-4 × Pioneer .....                | do. ....                               | 9                | 262                         | 97                   | 17                                   | 56.5                          |
| Average .....                      |  |                  |                             |                      |                                      | 47.2                          |
| Marquis × Kubanka (C I 2094) ..... | <i>Vulgare</i> × <i>durum</i> .....    | 49               | 1,692                       | 794                  | 97                                   | 52.7                          |
| Marquis × Iumillo (C I 1736) ..... | do. ....                               | 4                | 135                         | 84                   | 9                                    | 31.1                          |
| Pioneer × D-4 .....                | do. ....                               | 9                | 296                         | 128                  | 11                                   | 53.0                          |
| Preston × Acme .....               | do. ....                               | 10               | 348                         | 167                  | 10                                   | 49.1                          |
| Average .....                      |  |                  |                             |                      |                                      | 46.5                          |
| Emmer × Marquis .....              | <i>Dicoccum</i> × <i>vulgare</i> ..... | 14               | 410                         | 299                  | 17                                   | 22.9                          |
| Emmer × Preston .....              | do. ....                               | 13               | 446                         | 293                  | 25                                   | 28.7                          |
| Average .....                      |  |                  |                             |                      |                                      | 25.8                          |
| Marquis × emmer .....              | <i>Vulgare</i> × <i>dicoccum</i> ..... | 9                | 270                         | 184                  | 10                                   | 28.2                          |
| Preston × emmer .....              | do. ....                               | 3                | 94                          | 62                   | 4                                    | 29.8                          |
| Average .....                      |  |                  |                             |                      |                                      | 29.0                          |

The main spike of individual plants of the parent and crosses was used for this study. There was an average of 4.7 per cent of barren florets in three varieties of *Triticum vulgare*. In four varieties of *T. durum* there was an average of 4.3 per cent, while emmer (Minnesota 1165) produced only 2.1 per cent of florets which formed no kernels. Since these are presumably homozygous, it seems fair to conclude that the percentages given show the average number of florets which did not set seed on account of causes other than sterility.

Three  $F_1$  crosses were studied in which a durum sort was the female parent and four in which durum was the male parent. The average



percentages of barren florets were 47.2 and 46.5, respectively. There was about the same percentage of barrenness in emmer  $\times$  Marquis, emmer  $\times$  Preston, and reciprocals—namely, 25.8 when emmer was the female parent and 29 when emmer was the male parent. Thus, there is apparently more sterility in the durum-Marquis cross than in the cross between emmer and Marquis.

Although no cytological examination was made to determine the time of degeneration, it seems very likely that there is ovule as well as pollen abortion. Barren florets, however, might be due to incompatibility of certain genetic combinations or to slow growth of the pollen tube which has been shown to occur in some species crosses (8, 9).

#### NATURAL CROSSES AS A POSSIBLE INDICATION OF STERILITY

In 1917 the  $F_2$  generation of durum  $\times$  Marquis and durum  $\times$  Haynes Bluestem, as well as the parent sorts, were grown together. Marquis is an awnless, glabrous chaffed wheat, Bluestem is an awnless wheat and has pubescent chaff, while the durum varieties used have glabrous chaff and are bearded. In the  $F_2$  generation of the durum-Marquis cross there were a few individual plants with hairy chaff. Since these may have been the result of natural hybridization, these plants were eliminated from further consideration.

In the  $F_3$  families of the durum-Marquis cross, each of which came from an individual  $F_2$  plant, there were some hairy-chaffed plants. In some families the number of plants with hairy chaff was rather large, and counts were made to determine the frequency of their occurrence. Fully bearded plants have always been found to breed true for this character (14). This fact supports the view that natural crossing may be the cause of the hairy plants found in several of the  $F_3$  families.

The most convincing evidence of natural crossing comes from the  $F_3$  generation grown from glabrous-chaffed, bearded  $F_2$  plants of crosses between Jumillo or Kubanka with Marquis. Table III records the number of plants produced in different families as well as the number of bearded smooth, hairy, intermediate-awned, and intermediate-awned glabrous-chaffed plants. It is significant that all plants with hairy chaff had intermediate awns. This would be expected in the  $F_1$  generation of a cross between bearded wheats and so-called awnless varieties such as Marquis or Bluestem. It is apparent that the amount of natural crossing varies in different families. For example, 196-26 produced 7 bearded, glabrous-chaffed plants and 7 intermediate-awned, hairy-chaffed plants, while family 214-35 produced 60 bearded plants.

The progeny of a few selected glabrous-chaffed, intermediate-awned  $F_2$  plants of the cross between Marquis and durum are classified in Table IV. The parent  $F_2$  sorts were classified as glabrous-chaffed, intermediate-awned. All such plants produced both bearded, awnless, and intermediate-awned plants in the  $F_3$  generation. Numerous hairy-chaffed

plants were observed. None of these were bearded, all having either intermediate or very short-tipped awns like those of the Marquis parent. The evidence points to the conclusion that the hairy-chaffed plants obtained in the  $F_3$  generation were the result of natural hybrids in the  $F_2$  generation.

TABLE III.—Number of hairy-chaffed intermediate-awned plants, glabrous-chaffed intermediate-awned plants, and glabrous-chaffed bearded plants in  $F_3$  families grown from bearded glabrous-chaffed  $F_2$  plants of crosses between *Triticum durum* and *T. vulgare*.

| Cross.                               | Number of plants. |                    |                            |                               |
|--------------------------------------|-------------------|--------------------|----------------------------|-------------------------------|
|                                      | Total.            | Bearded, glabrous. | Intermediate-awned, hairy. | Intermediate-awned, glabrous. |
| Tumillo $\times$ Marquis:            |                   |                    |                            |                               |
| 196-5.....                           | 37                | 37                 | 0                          | 0                             |
| 196-26.....                          | 14                | 7                  | 7                          | 0                             |
| 196-34.....                          | 131               | 114                | 16                         | 1                             |
| 198-21.....                          | 66                | 54                 | 9                          | 3                             |
| 199-8.....                           | 48                | 27                 | 19                         | 2                             |
| 199-9.....                           | 74                | 56                 | 17                         | 1                             |
| 225-24.....                          | 47                | 41                 | 6                          | 0                             |
| 227-4.....                           | 114               | 93                 | 12                         | 9                             |
| 228-24.....                          | 19                | 8                  | 9                          | 2                             |
| 228-35.....                          | 31                | 30                 | 1                          | 0                             |
| 229-21.....                          | 15                | 15                 | 0                          | 0                             |
| 232-13.....                          | 37                | 9                  | 26                         | 2                             |
| 232-14.....                          | 51                | 33                 | 10                         | 8                             |
| Average of 26 lines.....             | 381               | 302                | 73                         | 6                             |
| Marquis $\times$ Kubanka (C I 2094): |                   |                    |                            |                               |
| 208-4.....                           | 10                | 4                  | 6                          | 0                             |
| 203-10.....                          | 40                | 39                 | 1                          | 0                             |
| 211-23.....                          | 43                | 40                 | 2                          | 1                             |
| 214-35.....                          | 60                | 60                 | 0                          | 0                             |
| 217-18.....                          | 35                | 20                 | 5                          | 1                             |
| 218-1.....                           | 36                | 26                 | 10                         | 0                             |
| 221-14.....                          | 34                | 19                 | 10                         | 5                             |
| 222-10.....                          | 36                | 36                 | 0                          | 0                             |
| 222-33.....                          | 36                | 30                 | 3                          | 3                             |
| Average of 30 lines.....             | 495               | 412                | 54                         | 29                            |

TABLE IV.—Number of hairy-chaffed plants and glabrous-chaffed plants in the  $F_3$  families grown from intermediate-awned glabrous-chaffed  $F_2$  plants of cross between *Triticum vulgare* and *T. durum*

| Plant No.   | Number glabrous chaffed. | Number hairy-chaffed. |
|-------------|--------------------------|-----------------------|
| 223-7.....  | 32                       | 22                    |
| 218-8.....  | 65                       | 4                     |
| 217-5.....  | 28                       | 4                     |
| 211-22..... | 49                       | 27                    |
| 209-4.....  | 37                       | 9                     |
| 203-38..... | 26                       | 19                    |
| 203-3.....  | 95                       | 0                     |
| 214-21..... | 30                       | 0                     |

The fact that natural crossing often occurs in species crosses shows the necessity for caution in analyzing data, and unless unusual methods are employed to protect parent plants, the ancestry of the progeny can not be known with certainty.

#### EXPERIMENTS IN INHERITANCE OF RUST RESISTANCE

The 1918 data are considered most reliable in drawing conclusions on the inheritance of rust resistance. This is due first to the fact that all barberry bushes were removed from the immediate vicinity of the rust plot early in the spring of 1918, and second to the fact that the epidemic was induced by hand spraying with inoculations of rust spores from a known greenhouse culture of *Puccinia graminis tritici*.<sup>1</sup>

#### RUST INFECTION OF THE $F_1$ GENERATION COMPARED WITH THAT OF PARENTS

The epidemic in the rust plots was satisfactory, although there was but little rust in other wheat fields on University Farm.

A considerable number of  $F_1$  crosses between resistant durum and emmer wheats and Marquis, Preston, and Pioneer were grown in the rust plot. The percentages of stemrust infection on the  $F_1$  and parent sorts are given in Table V.

TABLE V.—Rust notes on parental varieties and  $F_1$  crosses between resistant and susceptible wheats, 1918

| Variety or cross.                | Percentage of stemrust. | Cross.                        | Percentage of stemrust. |
|----------------------------------|-------------------------|-------------------------------|-------------------------|
| Marquis .....                    | 40 to 70                | Marquis×Acme (C I 5284) ..... | 70                      |
| Preston .....                    | 70                      | Preston×Acme (C I 5284) ..... | 70                      |
| Pioneer .....                    | 40                      | Acme×Marquis .....            | 70                      |
| Acme .....                       | 10                      | D-4×Pioneer .....             | 40                      |
| D-4 .....                        | 10                      | Acme×Preston .....            | 70                      |
| Kubanka (C I 2094) .....         | 20                      | Marquis×emmer .....           | 10                      |
| Iumillo (C I 1736) .....         | 15                      | Emmer×Marquis .....           | 10                      |
| Emmer (Minn. 1163) .....         | 0                       | Emmer×Preston .....           | 15                      |
| Marquis×Iumillo (C I 1736) ..... | 40                      | Preston×emmer .....           | 15                      |
| Marquis×Kubanka (C I 2094) ..... | 40 to 70                |                               |                         |

Four durum varieties were tested. The highest percentage of rust infection was 20 on Kubanka (C I 2094), while there was only 10 per cent on D-4 and Acme. On all of these durum varieties the uredinia were smaller than on the common wheats, such as Marquis and Preston, which were very susceptible. Pioneer was also susceptible, but since it matures earlier than either Marquis or Preston, the percentage of infection was lower.

<sup>1</sup> The details of production of the epidemic were directed by J. G. Leach, a graduate student assistant of the Pathology Division. Mr. Leach had previous experience in this work at the Tennessee Agricultural Experiment Station.

The crosses between resistant durum wheats and Marquis, Preston, and Pioneer gave similar results, the  $F_1$  generation being rusted as badly as the susceptible common wheat parent.

Different results were obtained in the  $F_1$  crosses of emmer (Minnesota 1165) with Marquis and Preston. The emmer parent is practically immune from this form of *Puccinia graminis tritici* as determined both by field data and experiments in the greenhouse. Two crosses, Marquis  $\times$  emmer and Preston  $\times$  emmer, and reciprocals were studied. While a few small uredinia developed on the  $F_1$  generation, all plants observed were as free from rust as the resistant durum varieties. (See Pl. 97.)

That susceptibility is a dominant character in crosses between resistant durums and susceptible common wheats and a recessive character in crosses between resistant emmer and susceptible common wheats is obvious from these results. These facts bear out the observation made in the agronomy nursery in 1916—namely, that an  $F_1$  cross between emmer (Minnesota 1165) and Marquis was resistant, while in an adjacent row an  $F_1$  generation of a cross between a resistant durum and Marquis was severely infected.

#### CORRELATION BETWEEN RUST RESISTANCE AND BOTANICAL HEAD CHARACTERS

For the purpose of determining possible interrelation between inheritance of rust resistance and other differential characters, correlated individual plant data were taken on each  $F_2$  plant.

DURUM-COMMON CROSSES.—Notes were taken on length of head, number of spikelets, breadth of head in face and side views, average length of internode, condition of awns, and rust infection on each individual  $F_2$  plant. These plants were then classified into six groups—namely, emmerlike with seed inclosed by the glumes, durum, near-durum, intermediate, near-common, and common.

After the elimination of the emmerlike types the principal basis for classification was the appearance of the keel of the outer glume. In durum varieties the glumes are prominently and sharply keeled, while in the common wheats the outer glumes of the spikelets are only slightly keeled. The  $F_1$  generation of a cross between durum and common wheats was intermediate for this character (Pl. 98). This one character determined whether the plant in question approached more closely the durum or the common type. The breadth of head in face and side views, the presence or absence of the depression in the center of the outer glume, and the condition of the collar were used in making the final classification. The depression is characteristic of common wheats. In most durum wheats the collar at the base of the lower spikelet extends all around the neck of the culm, while in common wheats it extends only part way around. Since progeny of the  $F_2$  plants were grown in the  $F_3$  generation, mistakes in classification were rectified. The individuals finally placed

in the durum, common, and emmer groups were those which bred true. Some of the near-durums may actually belong in the durum group, but there was no attempt to rectify unimportant mistakes in these classes.

The plants were placed in four rust infection groups: group 1, practically immune, 0 to 5 per cent infection; group 2, resistant, 10 to 20 per cent infection, uredinia smaller than in the normally susceptible varieties; group 3, susceptible, 25 to 40 per cent infection; and group 4, heavily infected. These groups were based on the behavior in the  $F_3$  generation of the progeny of each  $F_2$  plant.

In the  $F_2$  generation some spikes with glumes resembling common wheat were as compact as those of the durum parents or more so. These were very similar to the club wheats and were placed in the common group. Likewise, lax-headed, sharply keeled wheats were obtained which were placed in the durum group. No differentiation was made between emmer and spelt, all plants with adherent glumes being placed together. Forms were obtained, however, which closely resembled true spelt.

The results from Marquis  $\times$  Jumillo and Marquis  $\times$  Kubanka were similar, and the data were combined. In the final summary in Table VI each plant is classified as resistant or susceptible. The writers believe that the plants classified as resistant would not be seriously injured in a severe epidemic of this rust form. However, there is considerable variation within each group. The resistant plants belong to either class 1 or 2 for rust infection.

There were two classes of susceptible  $F_2$  plants, those which produced all susceptible progeny in the  $F_3$  generation and those which produced both resistant and susceptible progeny. All resistant plants bred true in the  $F_3$  generation; at least this was the criterion used to determine whether a particular  $F_2$  plant was really resistant.

Several conclusions can readily be drawn from Table VI. This is a tabulation of 404  $F_2$  plants, each of which was tested in the  $F_3$  generation. Of these 404 plants 4, 81, and 33 bred true to the botanical head type respectively of emmer, common, and durum. All 4 emmers and 8 out of 33 durums were resistant, while 81  $F_2$  common segregates were all susceptible. This strongly indicates that in these crosses resistance and susceptibility are linked in transmission with the botanical head characters which differentiate durum and common wheats. The results again show that it is easy to obtain resistant durums, while it is much more difficult, if not impossible, to obtain resistant common wheats.

As has already been mentioned, both lax and dense durumlike segregates (Pl. 99) as well as compact keelless common wheats were obtained. There seems, however, to be a relation between average length of internode and the botanical classes. Thus, the average mean head densities<sup>1</sup> of the five groups, durum, near-durum, intermediate,

<sup>1</sup> Density was calculated by dividing the length of the head in millimeters by the number of spikelets less one.

near-common, and common are 3.30, 3.77, 4.08, 3.94, and 4.40, respectively. A correlation coefficient of  $+0.244 \pm 0.028$  for density and head characters was obtained.

TABLE VI.— $F_2$  Marquis  $\times$  Iumillo (CI 1736) and Marquis  $\times$  Kubanka (CI 2094)<sup>1</sup>

[R=resistant to stemrust. S=susceptible to stemrust]

| Density.   | Durum. |       | Near-durum. |       | Inter-mediate. |       | Near-common. |       | Common. |    | Emmer. |       |
|------------|--------|-------|-------------|-------|----------------|-------|--------------|-------|---------|----|--------|-------|
|            | R.     | S.    | R.          | S.    | R.             | S.    | R.           | S.    | R.      | S. | R.     | S.    |
| <i>Mm.</i> |        |       |             |       |                |       |              |       |         |    |        |       |
| 2.5.....   | 3      | 4     | 2           | 12    | .....          | 9     | .....        | 12    | .....   | 4  | .....  | ..... |
| 3.0.....   | 3      | 8     | 5           | 28    | .....          | 3     | .....        | 20    | .....   | 16 | .....  | 6     |
| 3.5.....   | 2      | 5     | 2           | 29    | .....          | 6     | .....        | 19    | .....   | 14 | .....  | 12    |
| 4.0.....   | .....  | 4     | 6           | 22    | .....          | 2     | .....        | 26    | .....   | 1  | .....  | 19    |
| 4.5.....   | .....  | 4     | 3           | 20    | .....          | 2     | .....        | 21    | .....   | 14 | .....  | 10    |
| 5.0.....   | .....  | ..... | .....       | ..... | .....          | 9     | .....        | 1     | .....   | 18 | .....  | 7     |
| 5.5.....   | .....  | ..... | .....       | 5     | .....          | ..... | .....        | 9     | .....   | 5  | .....  | 18    |
| 6.0.....   | .....  | ..... | .....       | 3     | .....          | ..... | .....        | 8     | .....   | 1  | .....  | 6     |
|            | .....  | ..... | .....       | ..... | .....          | ..... | .....        | ..... | .....   | 6  | .....  | 9     |
|            | 8      | 25    | 19          | 128   | 14             | 130   | 2            | 93    | 0       | 81 | 4      | 0     |
| Ratio..... | 1:3.1  |       | 1:6.7       |       | 1:9.3          |       | 1:46.5       |       | 0:81    |    | 4:0    |       |

<sup>1</sup> The coefficient of correlation between density of head and classes for durum, near-durum, intermediate, near-common, and common is  $+0.244 \pm 0.028$ .

$F_2$  generations in which the resistant durum parent was the female are given in Table VII, a total of 632 plants being classified on the basis of the  $F_3$  breeding test. Of these  $F_2$  plants 100 bred true to durum habit, 47 resembled common, while 3 were emmerlike. Sixteen out of 100 durumlike plants were resistant, while only 2 out of 47 classified as common were resistant. Of the three emmerlike plants, one was susceptible and the other two were resistant. Here, again, as with the reciprocal cross, there is an indication of linkage between common wheat head characters and susceptibility to stemrust. One intermediate susceptible  $F_2$  plant was grown in the  $F_3$  generation, and several plants were obtained with common head characters. One of these was very resistant and vigorous (Pl. 99).

The average densities of the durum, near-durum, intermediate, near-common, and common segregates were 3.76, 3.53, 4.06, 4.38, and 4.60, respectively, although both durum and common wheats were found in the extreme dense and lax groups. The coefficient of correlation between density and head type was  $+0.330 \pm 0.024$ .

In order to confirm field observations, a study was made in the greenhouse of the more resistant and susceptible durum, common, and emmer segregates obtained from the durum-common crosses. For head characters of types studied see Plate 101. Seedlings of  $F_3$  plants were

inoculated with the form of *Puccinia graminis tritici* which was used in obtaining the field epidemic. Three different tests of resistant and susceptible segregates of emmer, common, and durum  $F_3$  lines were made. The results are given in Table VIII. (See Pl. 102.)

TABLE VII.— $F_2$  Iumillo (C I 1736)  $\times$  Marquis and Kubanka (C I 2094)  $\times$  Marquis<sup>1</sup>

[R= resistant to stemrust. S= susceptible to stemrust]

| Density.   | Durum. |    | Near-durum. |     | Intermedi-ate. |     | Near-common. |     | Common. |    | Emmer. |    |
|------------|--------|----|-------------|-----|----------------|-----|--------------|-----|---------|----|--------|----|
|            | R.     | S. | R.          | S.  | R.             | S.  | R.           | S.  | R.      | S. | R.     | S. |
| <i>Mm.</i> |        |    |             |     |                |     |              |     |         |    |        |    |
| 2.5        | 1      | 7  | 4           | 19  | 2              | 11  |              | 2   |         | 3  | 1      |    |
| 3.0        | 8      | 24 | 11          | 40  |                | 22  | 2            | 15  | 2       |    |        | 1  |
| 3.5        | 3      | 18 | 6           | 27  | 2              | 30  | 1            | 8   | 1       | 6  |        |    |
| 4.0        | 2      | 7  | 3           | 22  | 2              | 47  | 1            | 24  |         | 6  |        |    |
| 4.5        |        | 10 | 1           | 19  | 2              | 43  | 1            | 21  |         | 7  |        |    |
| 5.0        | 1      | 13 | 1           | 9   |                | 31  |              | 16  |         | 6  | 1      |    |
| 5.5        |        | 2  |             | 2   |                |     |              | 20  | 1       | 6  |        |    |
| 6.0        | 1      | 3  |             | 1   |                | 6   |              | 6   |         | 9  |        |    |
|            | 16     | 84 | 26          | 139 | 8              | 192 | 5            | 112 | 2       | 45 | 2      | 1  |
| Ratio....  | 1:5.3  |    | 1:5.3       |     | 1:24.0         |     | 1:22.4       |     | 1:22.5  |    | 1:0.5  |    |

<sup>1</sup> The coefficient of correlation between density and type as durum, near-durum, intermediate, near-common, and common is  $+0.350 \pm 0.024$ .

TABLE VIII.—Comparison of resistant and susceptible  $F_3$  lines with Marquis, Kubanka (C I 2094), and Iumillo (C I 1736)<sup>1</sup>

| Source.                        | Plant No.  | Type.  | Num-ber inocu-lated. | Num-ber in-fected. | Remarks.  |
|--------------------------------|------------|--------|----------------------|--------------------|---|
| Marquis                        | Minn. 1239 | Common | 10                   | 10                 | Extremely susceptible.  |
| Kubanka                        | C I 2094   | Durum  | 12                   | 10                 | Moderately susceptible with slight chlorosis under infected areas.  |
| Kubanka $\times$ Marquis $F_3$ | 222-12     | Emmer  | 18                   | 8                  | Extremely resistant; uredinia minute, surrounded by sharp hypersensitive areas; 8 plants were strongly flecked. |
| Kubanka $\times$ Marquis $F_3$ | 222-30     | do.    | 11                   | 16                 | Highly susceptible; infection normal.   |
| Iumillo $\times$ Marquis $F_3$ | 181-24     | Common | 14                   | 12                 | Highly susceptible; infection normal.   |
| Iumillo $\times$ Marquis $F_3$ | 186-13-5   | do.    | 21                   | 4                  | Infection moderate with slight chlorosis under infected areas; 7 plants were strongly flecked.                  |
| Iumillo $\times$ Marquis $F_3$ | 228-37     | Durum  | 17                   | 8                  | Moderately resistant with chlorosis under infected areas; 2 plants were distinctly flecked.                     |
| Iumillo $\times$ Marquis $F_3$ | 186-15     | do.    | 20                   | 19                 | Highly susceptible; infection normal.   |
| Iumillo                        | C I 1736   | do.    | 22                   | 11                 | Slightly susceptible; 4 plants were distinctly flecked with slight chlorosis under some infected areas.         |

<sup>1</sup> The authors wish to express their thanks to M. N. Levine, Assistant Pathologist, Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, for preparing Table VIII and Plate 102 and for conducting the greenhouse experiment on which they are based.

These families were selected in the field as examples of resistant and susceptible  $F_2$  lines. Since the inoculation results in the greenhouse corroborate the field observations, there is good reason for believing that the field observations are reliable. This greenhouse experiment shows clearly that transgressive segregation occurred. Common, durum, and emmer sorts were obtained with a higher degree of resistance than that of either of the durum parents.

These results show that, if the numbers are sufficiently large, it is possible to obtain resistant wheats with common head characters by crossing resistant durum and susceptible common varieties. In the  $F_2$  generation, out of a total of 128 common segregates only 2 were rust-resistant, and both of these were of little commercial value. However, several resistant plants with the head characters of common wheats were obtained in the  $F_3$  generation.

EMMER-COMMON CROSSES.—Only a few plants were available for the study of crosses between emmer and common varieties. Two different white spring emmers (Minnesota 1165 and C I 1524) were used in this study. Minnesota 1165 is a very vigorous variety which was practically immune from the form of stemrust experimented with, both in the field and in the greenhouse. C I 1524 is quite similar to Minnesota 1165, except that it occasionally produces small uredinia.

The difference between emmer and common wheat is greater than that between durum and common wheat. The shape of the head of the emmer parent, which is proportionally very narrow in face view, together with the strongly keeled glumes, differentiates it from the Marquis parent. The kernels of emmer are tightly inclosed by the glumes, and recognition is easy.

The  $F_1$  generation of the cross between emmer and common is intermediate for the differential characters mentioned above as separating the parent sorts (Pl. 98). The keels of the  $F_1$  generation are intermediate, but they more closely resemble those of the emmer parent. The head shape of the  $F_1$  generation is likewise more nearly emmerlike. Fifty-six per cent of the kernels were naked and 44 per cent had adherent glumes after they were thrashed in an individual plant thrasher. The emmer parent produced 19 per cent naked kernels and 81 per cent hulled kernels. The  $F_1$  generation (Table V) is nearly as resistant as the emmer parent. Thus, the  $F_1$  generation more nearly resembles emmer.

Fifty  $F_2$  plants of the cross between Marquis and emmer (Minnesota 1165) were grown in the  $F_2$  generation. Of this number 5 plants were emmers, and 1 was a very susceptible, lax, common type. The progeny of 5  $F_2$  plants thrashed like common wheats in the  $F_3$  generation, but the heads were very compact (Pl. 100). Two  $F_2$  plants bred true to the common keel condition and segregated, producing compact, intermediate,



and lax heads. Thirty-seven produced progeny consisting of types with inclosed emmerlike kernels, intermediates for thrashing, and common plants. Of these 37  $F_3$  lines, 17 produced progeny of only two sorts, emmerlike for thrashing and compact keelless (Pl. 100).

It is, of course, impossible to determine the actual factors involved in this cross, because some gametes or zygotes were eliminated by sterility.

The cross in which emmer (C I 1524) was the female parent gave results similar to those obtained when emmer was used as the male parent. This is shown in Table IX. One family, 169-5, which was grown from an intermediate  $F_2$  plant, produced emmers, intermediates, and common-headed sorts and was quite resistant (Pl. 100).

TABLE IX.—Classification of crosses between emmer (Minnesota 1165 and C I 1524) with Marquis on the basis of rust class in the  $F_2$  generation as determined by the  $F_2$  and  $F_3$  generations, and the main character differences separating emmer from common wheats as determined by the  $F_2$  and  $F_3$  generations

MARQUIS × EMMER 1165

| Rust class. | Emmer. | Segregating emmer to common. | With nonadherent glumes. |              |         | Total. |
|-------------|--------|------------------------------|--------------------------|--------------|---------|--------|
|             |        |                              | Compact.                 | Segregating. | Common. |        |
| 1.....      | 4      | 9                            | 1                        | 1            |         | 15     |
| 2.....      | 1      | 21                           |                          |              |         | 22     |
| 3.....      |        | 7                            | 4                        | 1            | 1       | 13     |
| Total.....  | 5      | 37                           | 5                        | 2            | 1       | 30     |

EMMER (C I 1524) × MARQUIS

| Rust class. | Emmer. | Segregating emmer to common. | With nonadherent glumes. |              | Total. |
|-------------|--------|------------------------------|--------------------------|--------------|--------|
|             |        |                              | Compact.                 | Segregating. |        |
| 1.....      | 3      | 3                            | 4                        |              | 10     |
| 2.....      |        | 6                            | 2                        | 1            | 9      |
| 3.....      |        | 2                            | 2                        |              | 4      |
| Total.....  | 3      | 11                           | 8                        | 1            | 23     |

It is interesting that out of a total of 73 plants from these two crosses, 8 bred true to the emmer habit for thrashing and for head shape. Of these 8, 7 plants were put in rust class 1 while 1 was practically resistant, the progeny in the  $F_3$  generation being placed in rust class 2. Only one lax, common plant was obtained in the  $F_2$  generation, and this was susceptible. Several plants were obtained in the  $F_3$  generation which were not only rust-resistant but also resembled common wheat.

These facts show that it is possible to transfer the rust resistance of emmer wheats to common wheats by crossing and subsequent selection. There is, however, an apparent partial linkage between rust resistance and the emmer head type which makes it essential to grow large numbers in the  $F_2$  and  $F_3$  generations.

#### SUMMARY

(1) Recent studies of the parasitism of the black stemrust of wheat (16, 18, 21, 24) have shown that there are many biologic forms of *Puccinia graminis* which can be differentiated only by their action on pure line wheat hosts. This seriously complicates the breeding of wheat for rust resistance. In the light of this knowledge differences of infection of certain crosses in 1917, as compared with 1916 or 1918, show that the conflicting results may be explained logically by supposing that more than one biologic form was present in the rust nursery in 1917.

(2) Sterility is a factor which must be considered in a study of crosses between common wheats and durum or emmer varieties. Sterility was shown in three ways: (a) pollen abortion; (b) the fact that  $F_1$  florets of durum-common crosses set nearly 50 per cent less kernels than the parent sorts, while  $F_1$  emmer-common crosses produced about 25 per cent of barren florets; and (c) the large number of natural crosses which occurred in some  $F_2$  plants as shown by the  $F_3$  results.

(3) Crosses between durum and common wheats produced many different forms in the  $F_2$  generation, such as compact keelless commons resembling club wheats, lax sharply keeled durums, both emmer and spelt, as well as types which resembled the poulard group. Lax and compact durum, common, and emmerlike forms were obtained which bred true in the  $F_3$  generation. The segregation in the  $F_2$  generation of emmer-common crosses was not so wide as in the durum-common cross, although both lax and compact keelless wheats which bore naked kernels, as well as lax and compact wheats with adherent-glumed kernels, were obtained.

(4) The study of inheritance of rust resistance was made in a specially prepared disease plot. Because of the conflicting results of 1916 and 1917 all barberry bushes were removed early in the spring of 1918 from the immediate vicinity of the rust plot and the epidemic was induced with a known form of rust. The data on rust infection are based on these 1918 results.

(5) The following species and varieties were used in the study: *Triticum vulgare*, varieties Preston, Marquis, and Pioneer; *Triticum durum*, varieties Acme, D-4, Kubanka (C I 2094), and Jumillo (C I 1736); *Triticum dicoccum*, White Spring emmer (Minnesota 1165 and C I 1524).

The three common wheats were susceptible, the durums were commercially resistant, Kubanka (C I 2094) being somewhat less resistant

than Iumillo (C I 1736), while Acme and D-4 were slightly more resistant than either of the other durum sorts. The emmer varieties were very resistant, Minnesota 1165 being practically immune.

(6) The  $F_1$  generation of crosses between durum and common varieties was as susceptible as the common parent, while  $F_1$  crosses between the practically immune emmer parents and susceptible commons were about as resistant as the durum varieties. Thus, in the cross where emmer is one parent, resistance is partially dominant, while in the durum-common cross susceptibility is completely dominant over resistance.

(7) Each  $F_2$  plant which produced viable seed was tested in the  $F_3$  generation for both rust infection and botanical characters. These  $F_3$  notes were used to determine the genotypic nature of individual  $F_2$  plants. In the crosses between durum and common in which Marquis was the female parent, 404  $F_2$  plants were tested in the  $F_3$  generation and no rust-resistant common wheats were obtained. Likewise, no plants in the  $F_3$  generation seemed especially promising for both common wheat characters and rust resistance. In the crosses in which durum was the female, one or two  $F_2$  common-headed plants were resistant; but their progeny were worthless from a practical agronomic standpoint. In one  $F_3$  family which was grown from a susceptible  $F_2$  plant, a number of resistant, vigorous plants were obtained which had common head characters. There is an indication of linkage of durum or emmer characters and rust resistance, since the production of rust-resistant durums or emmers in the  $F_2$  and  $F_3$  generations is comparatively easy and the production of resistant common wheats much more difficult.

(8) Resistant and susceptible plants obtained either in the  $F_2$  or  $F_3$  generation from crosses of durum and common parents were selected. Resistant and susceptible common, emmer, and durum wheats were available for this study. Greenhouse inoculation studies with a known strain of *Puccinia graminis tritici* showed that durum, common, and emmer type plants were obtained in the  $F_2$  or  $F_3$  generation which were more resistant than the resistant durum parents. Thus, we have transgressive segregation for rust resistance.

(9) The number of plants available for a study of inheritance between resistant emmer parents and Marquis was not very great. In the  $F_3$  generation several lax-headed wheats were obtained which had the head shape and naked kernels of common wheats and which were rust-resistant. This shows that rust-resistant common wheats can be obtained by crossing susceptible common varieties with resistant emmers.

(10) The mode of inheritance of rust resistance seems entirely comparable with the general Mendelian manner of inheritance of botanical and morphological characters. The technic of breeding for rust resistance is similar to that of breeding for agronomic characters.

## LITERATURE CITED

- (1) AARONSOHN, Aaron.  
1910. AGRICULTURAL AND BOTANICAL EXPLORATIONS IN PALESTINE. U. S. Dept. Agr. Bur. Plant Indus. Bul. 180, 64 p., illus., 9 pl.
- (2) BIFFEN, R. H.  
1907. STUDIES IN THE INHERITANCE OF DISEASE-RESISTANCE. *In Jour. Agr. Sci.*, v. 2, pt. 2, p. 109-128.
- (3) ———  
1912. STUDIES IN THE INHERITANCE OF DISEASE RESISTANCE. II. *In Jour. Agr. Sci.*, v. 4, pt. 4, p. 421-429.
- (4) ———  
1916. THE SUPPRESSION OF CHARACTERS ON CROSSING. *In Jour. Genetics*, v. 5, no. 4, p. 225-228.
- (5) ———  
1917. SYSTEMATIZED PLANT BREEDING. *In* Seward, A. C., ed. *Science and the Nation*. . . . p. 146-175. Cambridge, [Eng.]
- (6) BLARINGHEM.  
1914. SUR LA PRODUCTION D'HYBRIDES ENTRE L'ENGRAIN (TRITICUM MONOCOCCUM L.) ET DIFFÉRENTS BLÉS CULTIVÉS. *In* *Compt. Rend. Acad. Sci. [Paris]*, t. 158, no. 5, p. 346-349, 1 fig.
- (7) CASTLE, W. E., and LITTLE, C. C.  
1910. ON A MODIFIED MENDELIAN RATIO AMONG YELLOW MICE. *In* *Science*, n. s. v. 32, no. 833, p. 868-870.
- (8) DORSEY, M. J.  
1919. A STUDY OF STERILITY IN THE PLUM. *In* *Genetics*, v. 4, no. 5, p. 417-488, 5 pl. Literature cited, p. 481-487.
- (9) EAST, E. M., and PARK, J. B.  
1918. STUDIES ON SELF-STERILITY. II. POLLEN-TUBE GROWTH. *In* *Genetics*, v. 3, no. 4, p. 353-366. Literature cited, p. 365-366.
- (10) ENGLEADOW, F. L.  
1915. REPULSION IN WHEAT. *In* *Amer. Nat.*, v. 49, no. 578, p. 127.
- (11) EVANS, I. B. Pole.  
1911. SOUTH AFRICAN CEREAL RUSTS, WITH OBSERVATIONS ON THE PROBLEM OF BREEDING RUSTY-RESISTANT WHEATS. *In* *Jour. Agr. Sci.*, v. 4, pt. 1, p. 95-104. Bibliography, p. 104.
- (12) FREEMAN, George F.  
1917. LINKED QUANTITATIVE CHARACTERS IN WHEAT CROSSES. *In* *Amer. Nat.*, v. 51, no. 611, p. 683-689.
- (13) ———  
1919. THE HEREDITY OF QUANTITATIVE CHARACTERS IN WHEAT. *In* *Genetics*, v. 4, no. 1, p. 1-93. Literature cited, p. 93.
- (14) HOWARD, Albert, and HOWARD, Gabrielle L. C.  
1915. ON THE INHERITANCE OF SOME CHARACTERS IN WHEAT. II. *In* *Mem. Dept. Agr. India Bot. Ser.*, v. 7, no. 8, p. 273-285, 8 pl.
- (15) KEZER, Alvin, and BOYACK, Breeze.  
1918. MENDELIAN INHERITANCE IN WHEAT AND BARLEY CROSSES. *Colo. Agr. Expt. Sta. Bul.* 249, 139 p., 10. fig., 9 col. pl.
- (16) LEVINE, M. N., and STAKMAN, E. C.  
1918. A THIRD BIOLOGIC FORM OF PUCCINIA GRAMINIS ON WHEAT. *In* *Jour. Agr. Research*, v. 13, no. 12, p. 651-654.
- (17) LITTLE, C. C.  
1919. A NOTE ON THE FATE OF INDIVIDUALS HOMOZYGOUS FOR CERTAIN COLOR FACTORS IN MICE. *In* *Amer. Nat.*, v. 53, no. 625, p. 185-187.

- (18) MELCHERS, Leo E., and PARKER, J. H.  
1918. ANOTHER STRAIN OF PUCCINIA GRAMINIS. *Kansas Agr. Exp. Sta. Circ.*  
68, 4 p.
- (19) MULLER, Hermann J.  
1918. GENETIC VARIABILITY, TWIN HYBRIDS AND CONSTANT HYBRIDS, IN A CASE  
OF BALANCED LETHAL FACTORS. *In Genetics*, v. 3, no. 5, p. 422-499.  
Literature cited, p. 497-498.
- (20) NILSSON-EHLE, H.  
1911. KREUZUNGSUNTERSUCHUNGEN AN HAFER UND WEIZEN. II. *Lunds Univ.*  
*Årsskr.*, n. F. Afd. 2, Bd. 7, No. 6, 82 p.
- (21) STAKMAN, E. C., and PIEMEISEL, F. J.  
1917. A NEW STRAIN OF PUCCINIA GRAMINIS. (Abstract.) *In Phytopathology*,  
v. 7, no. 1, p. 73.
- (22) ——— PARKER, J. H., and PIEMEISEL, F. J.  
1918. CAN BIOLOGIC FORMS OF STEPMYST ON WHEAT CHANGE RAPIDLY ENOUGH  
TO INTERFERE WITH BREEDING FOR RUST RESISTANCE? *In Jour. Agr.*  
*Research*, v. 1, no. 2, p. 111-123, pl.
- (23) ——— PIEMEISEL, F. J., and LEVINE, M. N.  
1918. PLASTICITY OF BIOLOGIC FORMS OF PUCCINIA GRAMINIS. *In Jour. Agr.*  
*Research*, v. 15, no. 4, p. 221-249, pl. 17-18.
- (24) ——— LEVINE, M. N., and LEACH, J. G.  
1919. NEW BIOLOGIC FORMS OF PUCCINIA GRAMINIS. *In Jour. Agr. Research*,  
v. 16, no. 3, p. 103-105.
- (25) TSCHERMAK, Erich v.  
1913. ÜBER SELTENE GETREIDEBASTARDE. *In Beitr. Pflanzenzucht*, Heft 3,  
p. 49-61, fig. 10.
- (26) VILMORIN, M. H.  
1880. ESSAIS DE CROISEMENT ENTRE BLÉS DIFFÉRENTS. *In Bul. Soc. Bot.*  
*France*, t. 27 (s. 2, t. 2), p. 356-361, pl. 6-7.
- (27) ———  
1883. EXPÉRIENCES DE CROISEMENT ENTRE DES BLÉS DIFFÉRENTS. *In Bul.*  
*Soc. Bot. France*, t. 30 (s. 2, t. 5), p. 58-63.



PLATE 97.

- A.—Pollen grains of Marquis wheat.
- B.—F<sub>1</sub> Marquis×Kubanka (C I 2094), showing sterile grains.
- C.—Pollen grains of Kubanka (C I 2094).
- D.—Stems of Kubanka (C I 2094) grown under rust-epidemic conditions. Note absence of rust infection.
- E.—F<sub>1</sub> Kubanka (C I 2094)×Marquis, showing normal uredinia.
- F.—Marquis, the susceptible parent.
- H.—F<sub>1</sub> emmer (Minnesota 1165)×Marquis, showing no normal uredinia.
- I.—Minnesota 1165, the resistant emmer parent. Note that in the durum-common cross the F<sub>1</sub> generation is susceptible while in the emmer-common cross the F<sub>1</sub> generation is resistant.

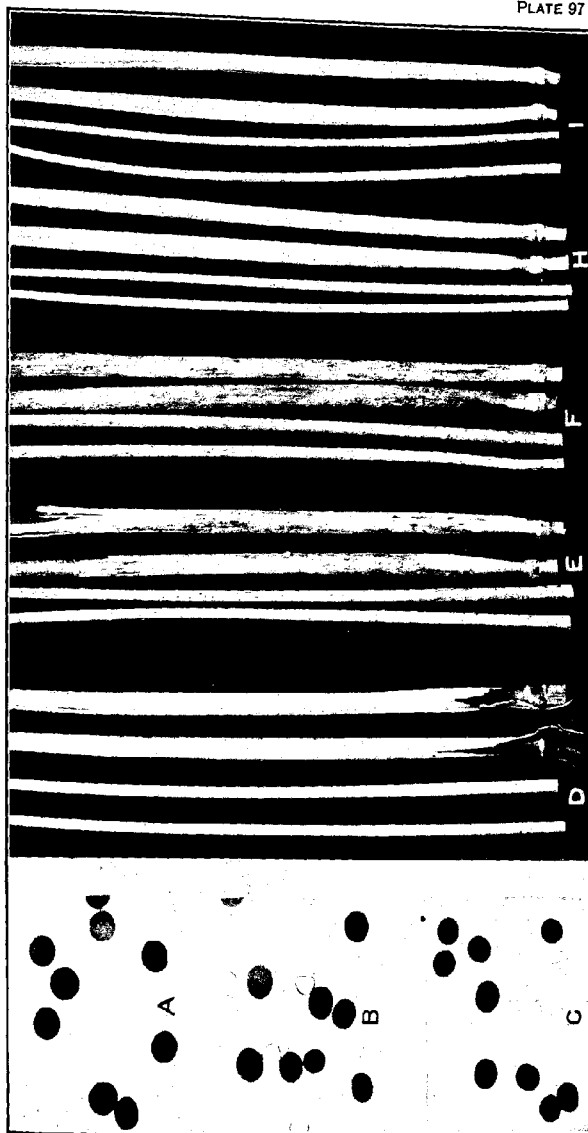






PLATE 98.

A, B, C.—Face and side views, respectively, of heads of Iumillo (C I 1736),  $F_1$  Iumillo  $\times$  Marquis, and Marquis. The  $F_1$  heads are intermediate in density and have tipped awns. The outer glumes are keeled, although not so strongly as Iumillo.

D, E, F.—Face and side views, respectively, of heads of emmer, Minnesota 1165,  $F_1$  emmer  $\times$  Marquis, and Marquis. The  $F_1$  generation approaches the emmer in some head characters and has intermediate awns.

G, H, I.—Kernels of Marquis,  $F_1$  emmer  $\times$  Marquis, and emmer. The  $F_1$  kernels are longer than Marquis, approaching those of the emmer parent in average length.

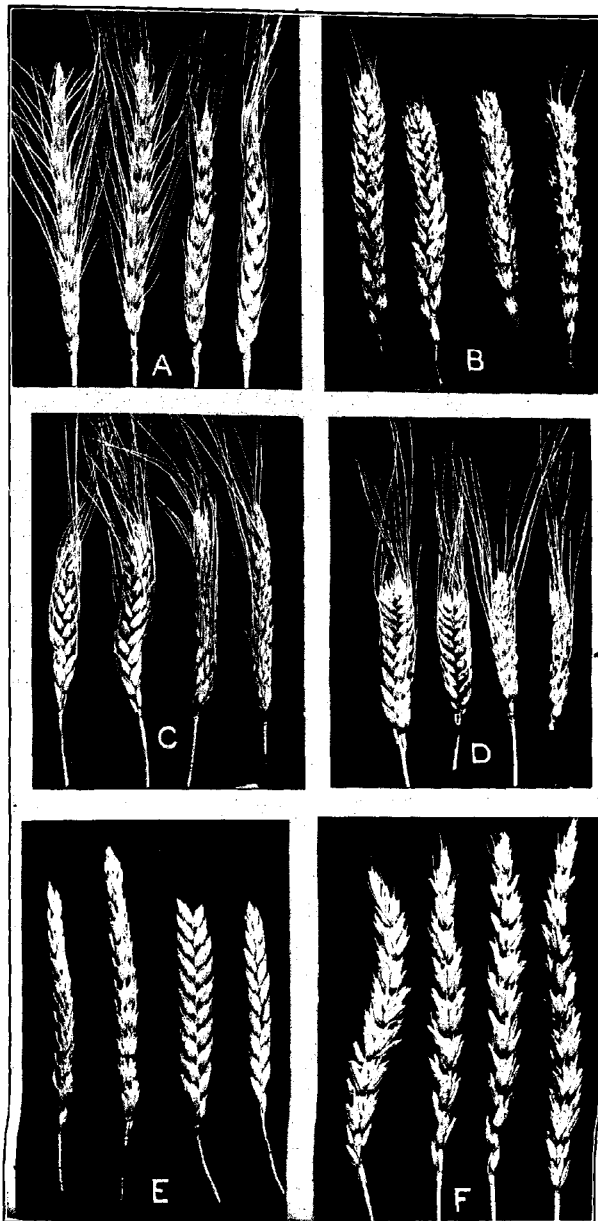
PLATE 99.

Representative heads of  $F_3$  families of the cross between durum and Marquis.

A, B, C, D.— $F_3$  families which were classified as durums. Note that these represent all types of head density.

E.—Heads of an awnless  $F_3$  emmer family.

F.—Four heads of an  $F_3$  plant which resembles common wheat in head shape and is rust-resistant.



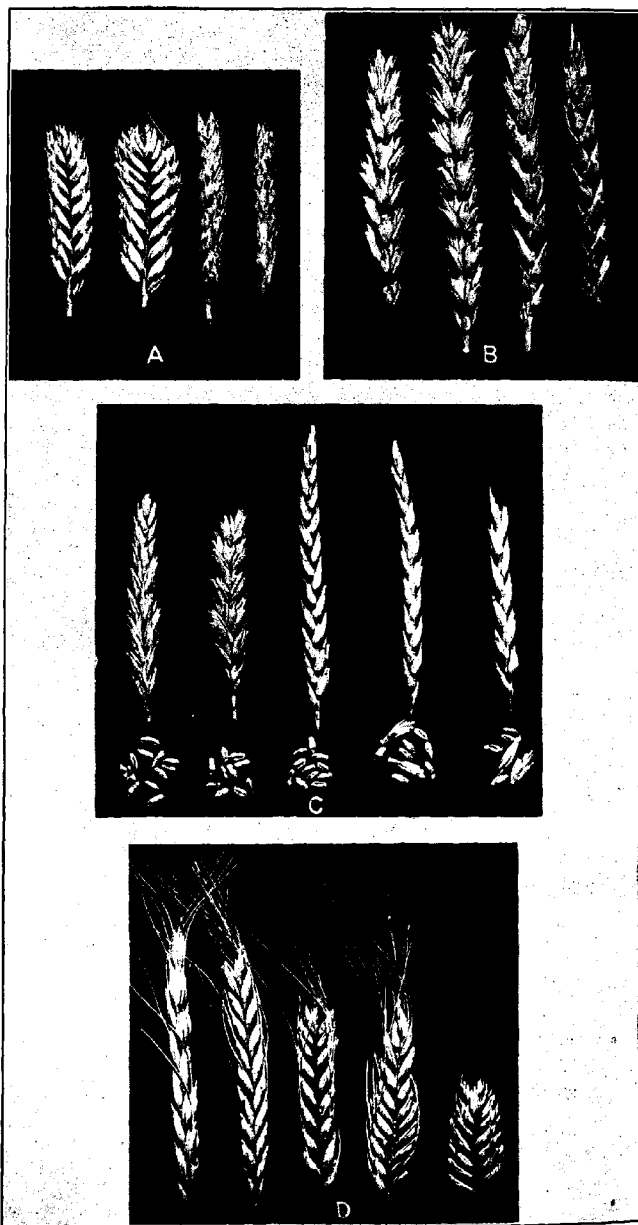


PLATE 100.

A.— $F_3$  family of a cross between emmer (Minnesota 1165), and Marquis, showing face and side view. This family proved rust-resistant and was also pure for keelless, compact heads and thrashed like common wheat.

B.—Heads of an  $F_3$  family which resembled common wheat. It was rust-susceptible.

C.—Heads of different plants of an  $F_3$  family of a cross between emmer (C I 1524) and Marquis. The plants varied from emmerlike and intermediate forms to those resembling common wheat as shown at the left. This family bred true for rust resistance.

D.—Represents a very frequent sort of segregation obtained in the  $F_3$  generation. Many families gave only emmerlike and keelless, compact headed sorts which thrashed like common wheat.

PLATE 101.

Heads of resistant and susceptible wheat obtained in the  $F_3$  generation from the cross between Marquis and durum:

A.—Head representing resistant emmer type  $F_3$  family 222-32, Kubanka  $\times$  Marquis.

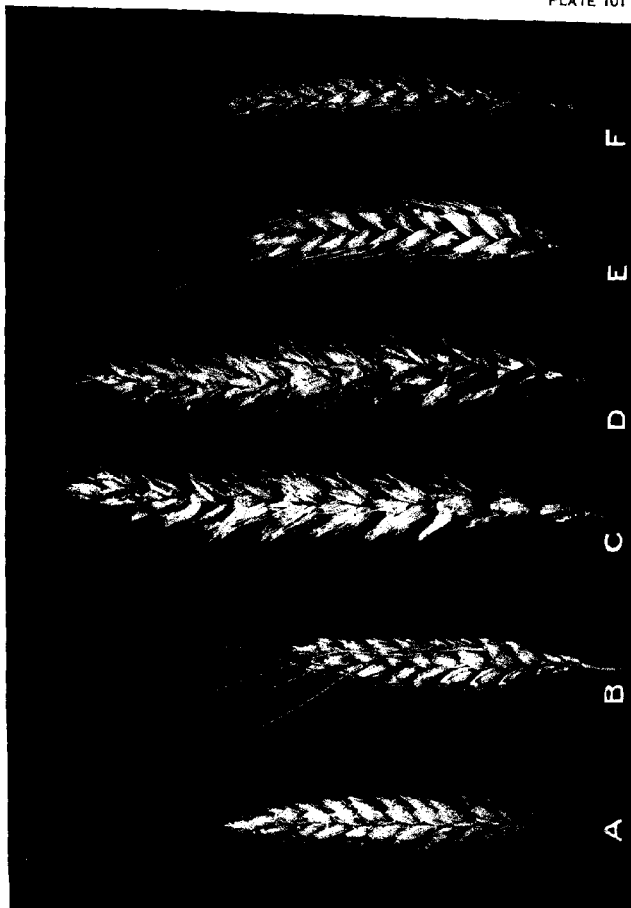
B.—Head representing susceptible emmer  $F_3$  family 222-30, Kubanka  $\times$  Marquis.

C.—Susceptible common  $F_3$  family 181-24, Iumillo  $\times$  Marquis.

D.—Resistant individual plant 186-13-5 which was obtained in the  $F_3$  generation of the cross between Iumillo  $\times$  Marquis.

E.—Resistant durum  $F_3$  family 228-37, Iumillo  $\times$  Marquis.

F.—Susceptible durum  $F_3$  family 186-15, Marquis  $\times$  Iumillo.





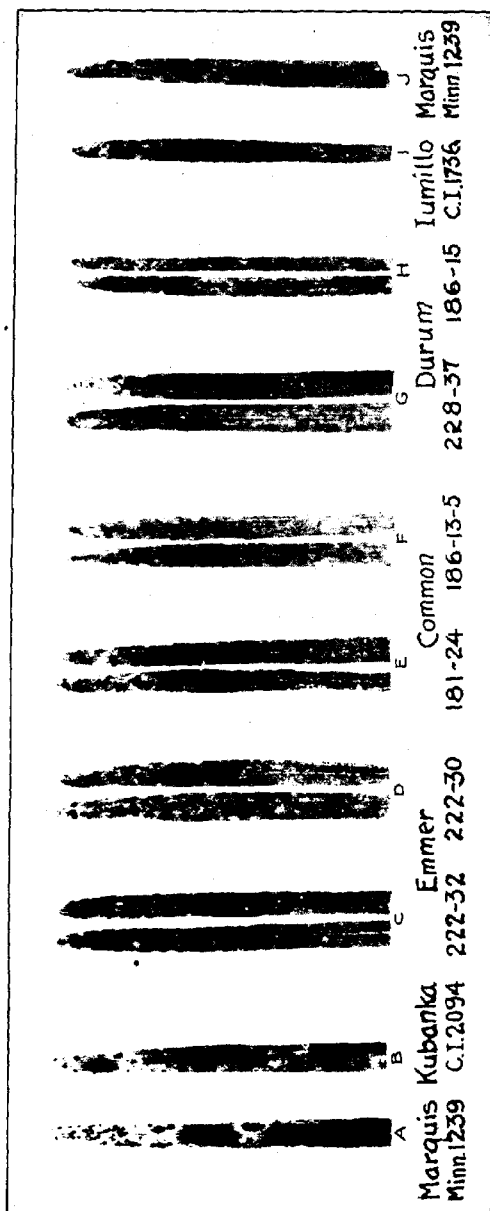


PLATE 102.

Greenhouse experiment:

- A.—Marquis, single blade, showing extreme susceptibility.
- B.—Kubanka (C I 2094), single blade; moderately susceptible with slight chlorosis.
- C.—Kubanka  $\times$  Marquis (222-32  $F_3$  emmerlike family); extremely resistant; uredinia minute surrounded by hypersensitive areas, or flecks.
- D.—Kubanka  $\times$  Marquis (222-30  $F_3$  emmerlike family); very susceptible.
- E.—Iumillo  $\times$  Marquis (181-24  $F_3$  common family); very susceptible.
- F.—Iumillo  $\times$  Marquis (186-13-5, an individual common plant of  $F_3$  family 186-13); moderately resistant with infected areas chlorotic.
- G.—Iumillo  $\times$  Marquis (228-37  $F_3$  durum family); moderately resistant with infected areas chlorotic.
- H.—Iumillo  $\times$  Marquis (186-15  $F_3$  durum family); fairly susceptible.
- I.—Iumillo (C I 1736), single blade; slightly susceptible.
- J.—Marquis (Minnesota 1239), single blade; highly susceptible.

The rust form used in the greenhouse experiment was the same as that used for the 1918 field epidemic.



## LINE-SELECTION WORK WITH POTATOES

By O. B. WHIPPLE

*Horticulturist, Montana Agricultural Experiment Station*

The data and discussions presented here have to do with the subject of potato-seed improvement through tuber selection. As such it deals with the improvement of existing varieties and may be contrasted with another type of potato breeding which, through the mediums of fertilization, production of seed, and growing of seedlings, aims at the origin of new varieties.

In the language of the plant breeder potato varieties are termed clons or clonal varieties. To him they differ from varieties of wheat, barley, or corn in that they are propagated from vegetative parts. Sexual reproduction or the use of seeds is resorted to only as a means of originating new varieties, not as a means of perpetuating existing ones. Varieties of wheat, barley, or corn reproduce true from seed, while clonal varieties do not. In other words, if we plant pure seed of yellow corn or blue barley, we harvest yellow corn or blue barley, but if we should plant seeds of red apples or red potatoes it is very doubtful if we should harvest either red apples or red potatoes. Few, if any, will doubt the value of potato-breeding work which has for its object the origin of new varieties from seed. Most of our potato varieties have originated as seedlings, either chance seedlings or those resulting from carefully planned breeding work. This phase of potato breeding is still attracting the attention of both scientific and amateur plant breeders, and new seedlings are constantly being introduced for trial. Some of these are real additions to potato culture, and others prove of only local and passing interest.

The improvement of clonal varieties through bud selection has been the subject of much discussion and the basis for much experimental study. In propagation, the horticulturist deals largely with clons or varieties which must be perpetuated by transplanting vegetative parts. Fruit trees, small fruits, many ornamental plants, nut trees, bulbous and tuberous plants, and many flowers, particularly greenhouse specialties, fall in this class. This line of plant breeding is of just as vital importance as the other which aims at improvement through crossing and hybridization and the growing of new seedlings. Potatoes have been the subject of much study along this line, the work of East,<sup>1</sup> Eustace,<sup>2</sup>

<sup>1</sup> EAST, EDWARD M. A STUDY OF THE FACTORS INFLUENCING THE IMPROVEMENT OF THE POTATO. III. *Ag. Exp. Sta. Bul.* 327, p. 375-456, 10 fig. 1908. Bibliography, p. 450-456.

— THE TRANSMISSION OF VARIATIONS IN THE POTATO IN ASEXUAL REPRODUCTION. *In Conn. Agr. Exp. Sta. Rpt.* 1909/10, p. 119-160, 5 pl. 1910.

<sup>2</sup> EUSTACE, H. J. AN EXPERIMENT ON THE SELECTION OF "SEED" POTATOES: PRODUCTIVE VS. UNPRODUCTIVE HILLS. *In Proc. Soc. Hort. Sci.*, 1903/04, p. 60-62. 1905.

Waid,<sup>1</sup> and Zavitz<sup>2</sup> being the most important of that reported in America. It is safe to say, however, that the work done so far has not by any means cleared up the subject of selection within clonal varieties. At present we can not say that we have a clear vision of the possibilities or the limitations along this line of plant breeding. Since plants within clonal varieties vary, we have assumed that there is opportunity for improvement through selection just as in varieties that are propagated from seed. But to what extent we can make use of selection to perpetuate desirable variations within the clon and in this way improve these varieties is still a question.

The plant breeder recognizes in plants three types of variations: (1) fluctuations or modifications, (2) segregations or combinations, and (3) mutations. Fluctuations are such variations as appear as a result of variable environmental conditions and are by many considered non-heritable or nontransmittable from one generation to another, regardless of whether perpetuation is through seeds or vegetative parts. In other words, if we accept this theory of the nonheritability of fluctuations due to environment we can not expect to increase the average vigor of a potato variety by selecting seed tubers from especially vigorous hills so long as the variation in vigor might be attributed to environmental conditions. Segregations are heritable differences resulting from segregation and recombination of hereditary units. This type of variation appears within the population of new hybrids and crosses perpetuated by seeds rather than by vegetative multiplication. Among potatoes we could expect such variations to appear only among seedlings, and for this reason segregation can not be considered among the possibilities for improving potato varieties which are perpetuated vegetatively. Mutations are heritable variations which do not depend upon segregation and recombination. Mutations are supposed to be much rarer than the other variations mentioned. Among horticultural plants many clonal varieties have arisen in this way and have for many years been perpetuated true to type through vegetative multiplication. An excellent example of a mutant among potatoes is the Pearl, which originated as a mutation, or in common language, as a bud sport from the Blue Victor. This has occurred not only once but several times. In our own Blue Victor seed plot of 1918 there appeared such a variation. This mutant was a perfect Blue Victor with the exception that it was white instead of blue in color. In other words, it was a perfect Pearl. In this seed plot, seed pieces from each tuber were planted in consecutive hills. The hills were thinned to single stems, and just one

<sup>1</sup> GREEN, W. J., and WAID, C. W. POTATO INVESTIGATIONS. SPRAYING AND SEED SELECTION EXPERIMENTS; VARIETY TESTS. Ohio Agr. Exp. Sta. Bul. 174, p. 251-289, 18 fig. 1906.

WAID, C. W. RESULTS OF HILL SELECTION OF SEED POTATOES. In Amer. Breeders' Assoc. Rpt., v. 3, p. 191-199. 1907.

<sup>2</sup> ZAVITZ, C. A. [REPORT OF THE DEPARTMENT OF FIELD HUSBANDRY.] In 31st Ann. Rpt. Ontario Agr. Exp. Col. and Exp. Farm, 1905, p. 165-220. 1905.

plant appeared with white potatoes. This means that one eye from a typical Blue Victor tuber produced a plant which bore white potatoes while all other eyes from the same tuber produced plants with blue potatoes true to type. This hill of white potatoes will, if planted, give plants bearing only white potatoes, for these simple bud sports or simple vegetative mutants may be perpetuated by propagation from vegetative parts. Here, then, we have an excellent example of how new varieties appear by mutation, but apparently such bud sports do not appear frequently.

If we purpose to champion the cause of selection within potato clons we must either show that high-yielding mutants, less striking than the one just mentioned and possibly for this reason more often unobserved, frequently appear within the clon and form the basis for selection, or we must break down, so far as clonal varieties are concerned, the theory that all fluctuations, or modifications are nonheritable. The greater part of the data here presented is the result of work begun with the intent of throwing light upon the first question. Experiments are also under way bearing upon the heritability of fluctuations, but as yet the data are not sufficient to warrant publication.

No one, I think, will doubt the value of certain lines of potato seed-selection work. For instance, there is abundant evidence to show that under anything like favorable environmental conditions the yielding power of a variety may be maintained by careful selection. In other words, a system of seed-tuber production which aims at the annual elimination of diseased or degenerate hills will, except under the most unfavorable environmental conditions, maintain a high-yielding population of any variety. But aside from the elimination of these weak hills we may question whether any practical results will come from further effort. In this case we are eliminating the hills that are below the average in vigor, the loss of vigor being due to attacks of disease or to degeneration. A very satisfactory method of procedure in such selection efforts is well outlined in Circular 73 of this Station.<sup>1</sup> The extent to which yields are increased by such selection is largely determined by the stock started with, its susceptibility to disease, and the tendency of the particular variety to degeneration under existing climatic and soil conditions. Starting with a variety population containing a large percentage of degenerate or diseased plants, proper selection will bring about a marked increase in yield. In growing a variety that has degenerate tendencies under certain environmental conditions, such a system of selection will be found very helpful in maintaining the yielding power of the variety. For the purpose of illustration, some examples may be cited. Russet Burbank, as it has been grown at Bozeman, is a very stable variety. Very few diseased hills appear in the plots, and very

<sup>1</sup> WHIPPLE, O. B., A SEED PLOT METHOD OF POTATO IMPROVEMENT. *Mont. Agr. Exp. Sta. Circ. 73*, p. 72-73. 1917.

few degenerate plants are found. Irish Cobbler and Early Triumph have behaved in just the opposite way, at least so far as degeneration is concerned. Within the last two varieties, as grown under our conditions, intelligent selection will give surprising results. With the Russet Burbank, profitable increase in yield might result from selection, but the improvement would be in no way spectacular. This type of selection work aims at increased production through the elimination of plants yielding below the average of the population.

The first work in line selection was undertaken in 1913 with the selection from the crop of that year of a few high-yielding hills of Russet Burbank (hills 201 to 206) and Rural New Yorker (hills 207 to 212). These have now been tested for five years, and a summary of the results is given in Table I. While these data do not represent a very large amount of experimental evidence, I believe that the results indicate what can be expected when effort is made to isolate high-yielding clonal lines by hill selection and maintain them by mass selection based upon tuber characteristics. Every effort was made to eliminate experimental errors. Seed pieces were dropped 15 inches apart in rows 3 feet 9 inches apart. Single-row plots were used with outside or guard rows in every case. In 1914, these plots were necessarily small. In 1915, 1/40-acre plots were used, and since 1915 plots of approximately 1/20-acre have been grown. No special effort has been made to control the size of the seed piece; but in 1914, 1915, and 1916 the plots were thinned to single-stemmed hills. This method gives promise of being as reliable as one based on the planting of uniform-sized seed pieces, for size of seed piece appears to influence yield only in so far as it is correlated with the number of stems produced in the hill. In other years the size of seed pieces could not have varied greatly, since the plan of cutting tubers of certain sizes to so many seed pieces was followed, without reference to number of eyes. The hills selected in 1913 were single-stemmed hills and were chosen on yield and tuber characteristics entirely. Of a large number of hills dug with a fork, those were selected which gave the greatest weight of tubers of good form. Tubers considered of good form were those long for the variety, full and rounded at both ends, and oval rather than round in cross section. In choosing seed by mass selection, the same form characteristics were considered; and the seed was picked after the digger. The seed for control plots was chosen by mass selection from the population of the variety from which the hills originally came, selection being based upon the same tuber characteristics. Single-plot tests were employed.

In Table I, I wish to call attention not so much to the 5-year performance record of the hill lines as to the very marked variation between their yields in 1914 and 1915 when compared with the control plots. If we take the 5-year average as a reliable indicator, some of these lines are apparently better yielders than others. I believe, however, that an-

other 5 years added to these performance records will go a long way toward blotting out these apparent differences. It will be noted that all these hills gave a very large increase over the control plots in 1914. But the interesting feature of the records is that following mass selection in 1914, the average yield of these lines immediately falls, in 1915, to the level of that of the control plot. In this connection it should be borne in mind that these two varieties are very stable under conditions at the Station and that neither has shown any serious tendency toward degeneration. The increased production in 1914 can not be accounted for on the theory that degenerate or weak hills were common in the control plots in 1914, nor can the decrease in yield in 1915 be accounted for on the theory that mass selection introduced into these lines degenerate types which tended to lower the yield of 1915. I believe the data clearly indicate that hill selection brings only temporary increases in yield and that such selection does not isolate high-yielding lines which may be maintained as high-yielding population by mass selection based on tuber characteristics alone.

TABLE 1.—Five-year summary of yields of marketable tubers per acre from hills selected in 1913

| Hill No.     | 1914           | 1915           | 1916           | 1917           | 1918           | 5-year average. |
|--------------|----------------|----------------|----------------|----------------|----------------|-----------------|
|              | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>  |
| 201.....     | 14,764         | 13,350         | 8,552          | 23,580         | 10,849         | 14,219          |
| 202.....     | 19,446         | 12,461         | 7,456          | 20,537         | 13,497         | 14,579          |
| 203.....     | 18,409         | 12,543         | 8,880          | 23,394         | 13,600         | 15,377          |
| 204.....     | 19,924         | 10,930         | 8,515          | 23,404         | 13,033         | 15,173          |
| 205.....     | 18,207         | 12,947         | 7,572          | 18,724         | 10,750         | 13,641          |
| 206.....     | 13,839         | 11,898         | 7,744          | 18,353         | .....          | 12,958          |
| Average..... | 17,431         | 12,354         | 8,119          | 21,342         | 12,359         | 14,341          |
| Control..... | 11,836         | 12,917         | 8,766          | 19,143         | 17,424         | 14,023          |
| 207.....     | 14,157         | 11,823         | 7,509          | 21,675         | 14,061         | 14,025          |
| 208.....     | 12,251         | 14,278         | 5,406          | 19,514         | 16,425         | 13,574          |
| 209.....     | 18,513         | 9,873          | 6,969          | 22,511         | 20,490         | 15,671          |
| 210.....     | 17,936         | 8,560          | 6,218          | 20,932         | 15,007         | 13,731          |
| 211.....     | 17,616         | 8,826          | .....          | 16,090         | 21,141         | 15,918          |
| 212.....     | 18,315         | 7,700          | .....          | 20,328         | 11,685         | 14,507          |
| Average..... | 16,464         | 10,177         | 6,525          | 20,175         | 16,618         | 14,571          |
| Control..... | 10,257         | 9,961          | 6,069          | 20,165         | 17,214         | 12,733          |

In 1916 work of similar nature was undertaken upon a more extended scale. With the selection of 108 tuber units each of Green Mountain, Rural New Yorker, and Early Six Weeks, 324 tuber lines were established, which have now been carried through three seasons. Eight of these lines were thrown out from the Early Six Weeks as variety mixtures, most of the 8 being Early Rose, so the summary on this variety covers only 100 tuber lines. Rural New Yorker has been previously referred to as quite



stable. Green Mountain, as grown at Bozeman, has rather strong degenerate tendencies, but Early Six Weeks would be classed as almost as stable as Rural New Yorker, since no rapid decline in yield followed selection based upon tuber characteristics. Since in this work every effort has been made to overcome the possibility of error, a discussion of methods will be in order.

Tuber units were selected from the bin in the spring of 1916. In each variety these tubers were cut to a uniform weight by slicing off the stem end. The Green Mountain tubers were cut to 7 ounces, the Rural New Yorker to  $8\frac{3}{4}$  ounces, and the Early Six Weeks to  $6\frac{1}{2}$  ounces. The remaining portion of the tuber was then quartered lengthwise. Since 1916 seed pieces have been cut with a special cutter which cuts a seed piece approximately hemispherical in shape,  $1\frac{1}{4}$  inches across the face and  $\frac{3}{4}$  inch deep. Such seed pieces weigh approximately  $\frac{1}{3}$  ounce, or about 11 gm. Because of variation in depth of eyes, these seed pieces will differ somewhat in weight, the maximum variation within a variety usually not exceeding 2 gm. and in many cases not exceeding 1 gm. Groups of 20 seed pieces seldom show variation of over 15 gm. While these seed pieces may appear small, they have apparently given just as strong plants as seed pieces cut in the usual manner and weighing  $1\frac{1}{2}$  ounces. Seed pieces have been planted by hand and covered to a uniform depth of 3 inches. Single-plot tests have been used entirely. Such tests carried on over a series of years should give just as reliable results as duplicate or triplicate tests conducted for a shorter period. Duplicating plots complicates the work of seed selection. It is not safe to select seed from any one plot to continue the line the following season, and it is difficult to select a small composite sample from two or three plots. It is for this reason that the single-plot test was decided upon.

The 1916 plots consisted of 4 hills, and the 1917 and 1918 plots of 20 hills. The latter is the standard-sized plot adopted here for this work. The selections from each variety are arranged in a group with from 9 to 12 plots in a row and from 9 to 12 rows. There is no space between plots in the rows. The control plot consists of a single row near the center of the group running the length of the group of plots. Hills are planted 15 inches apart in rows 3 feet 9 inches apart. Seed is chosen from the plots before the tubers are assembled, and in this way it is secured from different portions of the plot. To illustrate, from a standard-sized plot 5 seed tubers are selected. Four seed pieces from each tuber are planted the following season in adjacent hills, and when this crop is harvested, effort is made to select one seed tuber from each group of four hills, or from each unit, as they are called later. The plots receive rather deep cultivation, are well ridged, and are commonly irrigated once. At any rate they all receive the same cultivation and irrigation. All hills are thinned to single stems as soon as the vines are strong enough to pull, or from five to six weeks after planting.

Since these small seed pieces give an average of only about  $1\frac{1}{2}$  stems per hill, the thinning is not a very great task. Careful records are kept of the number and weight of marketable tubers and culls. Yields are computed upon the basis of a perfect stand. Naturally this favors the plot with an imperfect stand, for a missing hill tends to raise the yield of adjacent hills. Stand records are kept, showing the position of missing hills. As yet there is no basis upon which to apply such records in correcting yields, but I hope to make use of these later. Careful notes are also kept upon vine characteristics. We are particularly interested in those that indicate degeneration. Three general types of vines—vigorous, semi-curlydwarf or with curlydwarf tendencies, and curly-dwarfs—are recognized.

The results of three seasons' work upon this project are presented here, not with the idea of proving the presence or the absence of high-yielding tuber lines within these 316 selections but rather for the purpose of calling attention to the difficulty of interpreting these performance records. If such a method of seed improvement is to be of real and practical value, especially in the hands of the average potato grower, it would seem that a 3-year test should give rather definite and dependable results. If the process is to be a longer one than this, then the method should be proposed for the potato specialist rather than for the rank and file of potato growers.

#### GREEN MOUNTAIN TUBER LINES 300 TO 408

In variety tests at this Station, the Green Mountain types have on an average given the highest yields of all varieties grown. Varieties belonging to this group have, however, varied rather widely in yields. They are more susceptible to scab, more inclined to degeneration, and produce tubers less desirable as to commercial form than the Rural New Yorker; but withal the type is a very promising main-crop commercial potato.

In Table II will be found the 3-year performance records of the 108 Green Mountain lines, expressed in yields of pounds per acre. Of the three groups of tuber lines, these have given the most noticeable variations in yields.

Line 332 ranks first with a 3-year average yield of 27,849 pounds per acre, while line 344 has a 3-year average of 3,841 pounds. When ranked on 3-year average tuber production by weight, the 20 highest-yielding lines assembled in the last column of Table III have given an average yield of 25,000 pounds per acre, while the 20 lowest-ranking, appearing in the last column of Table IV, have averaged 12,083 pounds.

In Tables III and IV it will be noticed that only a few of the lines appear as consistent high or low yielders. Several numbers will be found in both tables, showing that lines have swung from one extreme to the other.

TABLE II.—Three-year summary of yields of marketable tubers per acre from 108 Green Mountain tuber lines

| Tuber line No. | 1916    | 1917    | 1918    | 3-year average. |
|----------------|---------|---------|---------|-----------------|
|                | Pounds. | Pounds. | Pounds. | Pounds.         |
| 300.....       | 10,453  | 20,442  | 26,017  | 18,970          |
| 301.....       | 10,453  | 23,230  | 16,261  | 16,648          |
| 302.....       | 11,034  | 22,300  | 19,071  | 17,468          |
| 304.....       | 12,776  | 26,946  | 14,247  | 17,989          |
| 305.....       | 13,357  | 22,553  | 15,486  | 17,132          |
| 306.....       | 15,680  | 30,199  | 29,340  | 25,073          |
| 307.....       | 11,615  | 21,836  | 14,402  | 15,951          |
| 308.....       | 6,969   | 27,411  | 11,873  | 15,417          |
| 309.....       | 12,776  | 26,017  | 11,615  | 16,802          |
| 310.....       | 13,938  | 20,442  | 26,482  | 20,287          |
| 311.....       | 11,615  | 23,230  | 21,603  | 18,816          |
| 312.....       | 12,195  | 19,513  | 13,938  | 15,215          |
| 313.....       | 9,872   | 25,553  | 13,795  | 16,376          |
| 314.....       | 11,034  | 26,482  | 10,840  | 16,118          |
| 315.....       | 11,615  | 31,128  | 16,626  | 19,789          |
| 316.....       | 15,608  | 24,623  | 11,736  | 17,322          |
| 317.....       | 15,099  | 33,915  | 23,472  | 24,102          |
| 318.....       | 13,938  | 30,199  | 20,269  | 18,135          |
| 319.....       | 13,938  | 17,190  | 21,371  | 17,499          |
| 320.....       | 15,099  | 22,765  | 30,663  | 22,842          |
| 321.....       | 9,292   | 22,300  | 15,099  | 15,563          |
| 322.....       | 11,615  | 26,017  | 16,626  | 18,086          |
| 323.....       | 13,938  | 32,057  | 13,938  | 19,977          |
| 324.....       | 15,680  | 37,168  | 21,836  | 24,894          |
| 325.....       | 11,615  | 29,734  | 19,164  | 20,171          |
| 326.....       | 11,034  | 34,380  | 20,907  | 22,197          |
| 327.....       | 10,453  | 37,632  | 14,867  | 20,984          |
| 328.....       | 10,453  | 15,796  | 10,453  | 12,234          |
| 329.....       | 10,453  | 28,340  | 13,930  | 17,576          |
| 330.....       | 9,292   | 27,876  | 30,318  | 22,495          |
| 331.....       | 7,549   | 26,946  | 23,230  | 19,241          |
| 332.....       | 15,099  | 39,026  | 29,424  | 27,849          |
| 333.....       | 14,518  | 37,632  | 25,320  | 25,823          |
| 334.....       | 10,453  | 24,623  | 10,221  | 15,099          |
| 335.....       | 11,615  | 33,915  | 16,028  | 20,519          |
| 336.....       | 11,034  | 36,238  | 14,670  | 20,647          |
| 337.....       | 12,195  | 15,331  | 7,665   | 11,730          |
| 338.....       | 19,164  | 29,269  | 22,738  | 23,723          |
| 339.....       | 12,195  | 19,513  | 10,513  | 14,073          |
| 340.....       | 13,357  | 28,340  | 24,202  | 21,986          |
| 341.....       | 5,807   | 29,269  | 8,595   | 14,557          |
| 342.....       | 6,969   | 23,230  | 11,615  | 13,938          |
| 343.....       | 12,195  | 35,309  | 26,249  | 24,584          |
| 344.....       | 1,742   | 9,292   | 489     | 3,841           |
| 345.....       | 15,680  | 14,402  | 1,366   | 10,482          |
| 346.....       | 9,292   | 10,685  | 8,001   | 9,326           |
| 347.....       | 10,453  | 17,654  | 6,968   | 11,601          |
| 348.....       | 14,518  | 18,584  | 30,715  | 21,272          |
| 349.....       | 8,130   | 23,230  | 12,776  | 14,712          |
| 350.....       | 10,453  | 24,159  | 15,796  | 16,802          |
| 351.....       | 13,938  | 27,875  | 15,099  | 18,970          |
| 352.....       | 14,518  | 28,495  | 19,048  | 20,687          |
| 353.....       | 12,195  | 26,946  | 20,674  | 19,938          |
| 354.....       | 17,422  | 33,451  | 31,128  | 27,333          |
| 355.....       | 14,518  | 22,765  | 20,293  | 19,199          |
| 356.....       | 10,453  | 19,048  | 8,362   | 12,621          |
| 357.....       | 12,776  | 18,584  | 18,351  | 16,570          |
| 358.....       | 10,453  | 23,694  | 11,751  | 15,299          |
| 359.....       | 11,034  | 27,876  | 13,936  | 17,615          |

TABLE II.—Three-year summary of yields of marketable tubers per acre from 108 Green Mountain tuber lines—Continued

| Tuber line No.      | 1916    | 1917    | 1918    | 3-year average. |
|---------------------|---------|---------|---------|-----------------|
|                     | Pounds. | Pounds. | Pounds. | Pounds.         |
| 360.....            | 13,936  | 25,553  | 20,674  | 20,054          |
| 361.....            | 11,615  | 22,300  | 26,714  | 20,202          |
| 362.....            | 11,615  | 31,592  | 29,966  | 24,399          |
| 363.....            | 12,195  | 32,766  | 30,807  | 25,251          |
| 364.....            | 7,549   | 21,836  | 9,292   | 12,866          |
| 365.....            | 10,453  | 23,230  | 11,150  | 14,944          |
| 366.....            | 9,202   | 34,380  | 14,670  | 19,447          |
| 367.....            | 8,130   | 27,876  | 19,745  | 18,583          |
| 368.....            | 11,034  | 23,230  | 9,868   | 14,690          |
| 369.....            | 9,292   | 22,300  | 13,692  | 15,094          |
| 370.....            | 10,453  | 16,261  | 7,824   | 11,512          |
| 371.....            | 11,034  | 31,128  | 17,604  | 19,922          |
| 372.....            | 13,357  | 30,321  | 31,266  | 24,991          |
| 373.....            | 15,099  | 34,845  | 24,205  | 24,716          |
| 374.....            | 6,388   | 20,442  | 5,342   | 10,724          |
| 375.....            | 11,613  | 29,343  | 11,980  | 17,645          |
| 376.....            | 9,872   | 33,915  | 30,073  | 24,620          |
| 377.....            | 8,516   | 33,849  | 22,997  | 21,787          |
| 378.....            | 6,069   | 27,411  | 19,513  | 17,964          |
| 379.....            | 10,453  | 22,765  | 15,099  | 16,105          |
| 380.....            | 12,195  | 25,553  | 13,274  | 17,007          |
| 381.....            | 8,130   | 21,029  | 7,433   | 12,197          |
| 382.....            | 13,938  | 27,876  | 19,100  | 20,304          |
| 383.....            | 12,195  | 35,309  | 22,983  | 23,495          |
| 384.....            | 8,711   | 20,017  | 16,261  | 16,990          |
| 385.....            | 5,807   | 21,371  | 4,181   | 10,453          |
| 386.....            | 12,776  | 32,522  | 13,008  | 19,435          |
| 387.....            | 14,518  | 23,230  | 12,079  | 16,609          |
| 388.....            | 16,261  | 38,581  | 27,873  | 27,571          |
| 389.....            | 9,872   | 24,941  | 12,714  | 15,842          |
| 390.....            | 15,099  | 32,522  | 28,362  | 25,327          |
| 391.....            | 16,259  | 39,663  | 32,086  | 26,636          |
| 392.....            | 12,776  | 24,623  | 12,079  | 16,492          |
| 393.....            | 13,357  | 25,688  | 13,241  | 17,228          |
| 394.....            | 7,549   | 34,380  | 20,674  | 20,867          |
| 395.....            | 5,807   | 34,722  | 12,079  | 17,536          |
| 396.....            | 7,549   | 36,238  | 25,088  | 22,958          |
| 397.....            | 10,605  | 21,836  | 19,513  | 17,138          |
| 398.....            | 8,130   | 30,663  | 28,572  | 22,455          |
| 399.....            | 9,872   | 29,269  | 22,997  | 20,712          |
| 400.....            | 8,130   | 28,500  | 29,269  | 21,996          |
| 401.....            | 9,202   | 23,694  | 11,873  | 14,953          |
| 402.....            | 7,549   | 22,907  | 6,504   | 11,653          |
| 403.....            | 6,388   | 26,017  | 13,203  | 15,202          |
| 404.....            | 15,099  | 34,845  | 22,713  | 24,219          |
| 405.....            | 11,615  | 30,663  | 15,159  | 19,145          |
| 406.....            | 12,776  | 30,109  | 22,005  | 21,660          |
| 407.....            | 11,613  | 23,694  | 18,584  | 17,963          |
| 408.....            | 9,291   | 19,298  | 11,615  | 13,401          |
| Yearly average..... | 11,335  | 26,595  | 17,493  | 18,474          |

TABLE III.—Twenty highest annual rankings and 3-year average rankings from 108 Green Mountain tuber lines<sup>a</sup>

| 1918        |         | 1917       |         | 1916      |         | 3-year average. |         |
|-------------|---------|------------|---------|-----------|---------|-----------------|---------|
| Line No.    | Yield.  | Line No.   | Yield.  | Line No.  | Yield.  | Line No.        | Yield.  |
|             | Pounds. |            | Pounds. |           | Pounds. |                 | Pounds. |
| **391.....  | 32, 086 | 332.....   | 39, 026 | *338..... | 19, 105 | ***332....      | 27, 849 |
| *372.....   | 31, 296 | 388.....   | 38, 582 | 354.....  | 17, 423 | ***388....      | 27, 571 |
| ***354..... | 31, 128 | *333.....  | 37, 633 | 388.....  | 16, 261 | ***354....      | 27, 333 |
| *363.....   | 30, 807 | *327.....  | 37, 633 | 391.....  | 16, 259 | **391.....      | 26, 636 |
| **348.....  | 30, 715 | **324..... | 37, 168 | *306..... | 15, 680 | ***333....      | 25, 823 |
| **320.....  | 30, 603 | *396.....  | 36, 239 | *316..... | 15, 680 | **390.....      | 25, 327 |
| *330.....   | 30, 318 | *336.....  | 36, 239 | *345..... | 15, 680 | *363.....       | 25, 256 |
| **376.....  | 30, 073 | *343.....  | 35, 310 | 324.....  | 15, 680 | **306.....      | 25, 073 |
| *362.....   | 29, 966 | *383.....  | 35, 310 | 317.....  | 15, 099 | *372.....       | 24, 991 |
| ***332..... | 29, 424 | **104..... | 34, 845 | 373.....  | 15, 099 | **324.....      | 24, 894 |
| **306.....  | 29, 340 | **173..... | 34, 845 | 404.....  | 15, 099 | **373.....      | 24, 716 |
| *400.....   | 29, 209 | *395.....  | 34, 723 | 332.....  | 15, 099 | **376.....      | 24, 620 |
| *368.....   | 28, 572 | *394.....  | 34, 380 | 390.....  | 15, 099 | **343.....      | 24, 584 |
| **390.....  | 28, 362 | *360.....  | 34, 380 | 320.....  | 15, 099 | *362.....       | 24, 391 |
| ***388..... | 27, 873 | *326.....  | 34, 380 | *333..... | 14, 519 | **404.....      | 24, 219 |
| *361.....   | 26, 714 | 376.....   | 33, 916 | *387..... | 14, 519 | **317.....      | 24, 162 |
| *310.....   | 26, 482 | *335.....  | 33, 916 | *355..... | 14, 519 | *338.....       | 23, 723 |
| **343.....  | 26, 249 | **317..... | 33, 916 | *352..... | 14, 519 | *383.....       | 23, 495 |
| *300.....   | 26, 017 | *377.....  | 33, 849 | 348.....  | 14, 519 | *320.....       | 22, 842 |
| ***333..... | 25, 320 | 354.....   | 33, 451 | 310.....  | 13, 938 | *330.....       | 22, 495 |
|             |         |            |         | *318..... | 13, 938 |                 |         |
|             |         |            |         | *319..... | 13, 938 |                 |         |
|             |         |            |         | *323..... | 13, 938 |                 |         |
|             |         |            |         | *351..... | 13, 938 |                 |         |
|             |         |            |         | *382..... | 13, 938 |                 |         |

<sup>a</sup> The number of stars indicates how many times the line has appeared among the 20 highest-yielding lines. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. Four lines appear three times, 12 appear twice, and 29 appear only once.

TABLE IV.—Twenty lowest annual rankings and 3-year average rankings from 108 Green Mountain tuber lines<sup>a</sup>

| 1918        |         | 1917      |         | 1916      |         | 3-year average. |         |
|-------------|---------|-----------|---------|-----------|---------|-----------------|---------|
| Line No.    | Yield.  | Line No.  | Yield.  | Line No.  | Yield.  | Line No.        | Yield.  |
|             | Pounds. |           | Pounds. |           | Pounds. |                 | Pounds. |
| **344.....  | 489     | 344.....  | 9, 292  | 341.....  | 5, 808  | **314.....      | 3, 841  |
| *345.....   | 1, 368  | 346.....  | 10, 686 | 385.....  | 5, 808  | **346.....      | 9, 326  |
| ***385..... | 4, 181  | 345.....  | 14, 403 | *395..... | 5, 808  | ***385....      | 10, 453 |
| ***374..... | 5, 342  | 337.....  | 15, 332 | 374.....  | 6, 388  | **345.....      | 10, 462 |
| ***402..... | 6, 504  | 328.....  | 15, 796 | *403..... | 6, 388  | ***374....      | 10, 724 |
| **347.....  | 6, 968  | *330..... | 16, 261 | *378..... | 6, 969  | *370.....       | 11, 512 |
| ***381..... | 7, 433  | *319..... | 17, 190 | *342..... | 6, 969  | ***402....      | 11, 653 |
| **337.....  | 7, 665  | 347.....  | 17, 655 | *308..... | 6, 969  | **347.....      | 11, 691 |
| *370.....   | 7, 824  | *348..... | 18, 584 | 402.....  | 7, 550  | **337.....      | 11, 730 |
| **346.....  | 8, 001  | *357..... | 18, 584 | 364.....  | 7, 550  | ***381....      | 12, 197 |
| *356.....   | 8, 362  | 356.....  | 19, 049 | *394..... | 7, 550  | **328.....      | 12, 234 |
| **341.....  | 8, 595  | *408..... | 19, 299 | *396..... | 7, 550  | *356.....       | 12, 621 |
| *354.....   | 9, 292  | *339..... | 19, 513 | *331..... | 7, 550  | **364.....      | 12, 892 |
| *368.....   | 9, 808  | *312..... | 19, 513 | *349..... | 8, 131  | *408.....       | 13, 401 |
| *334.....   | 10, 221 | *310..... | 20, 442 | *367..... | 8, 131  | *342.....       | 13, 938 |
| *318.....   | 10, 269 | 374.....  | 20, 442 | *398..... | 8, 131  | **339.....      | 14, 073 |
| **328.....  | 10, 453 | *300..... | 20, 442 | *400..... | 8, 131  | **341.....      | 14, 557 |
| *339.....   | 10, 513 | 402.....  | 20, 907 | 381.....  | 8, 131  | *368.....       | 14, 690 |
| *314.....   | 10, 840 | 381.....  | 21, 029 | *377..... | 8, 517  | *349.....       | 14, 712 |
| *365.....   | 11, 150 | 385.....  | 21, 372 | *384..... | 8, 711  | *365.....       | 14, 944 |

<sup>a</sup> The number of stars indicates how many years the line has appeared among the 20 lowest-yielding lines. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. Four appear three times, 10 appear twice, and 28 appear only once.

If with these records before us we attempt to point out apparently promising lines, we must base our judgment either upon the frequency with which the line appears among the high-yielding lines or upon its performance as indicated by the 3-year average. The following 1918 field notes are upon the lines that have appeared at least two out of the three seasons among the 20 highest or that rank with the 20 highest according to the 3-year average.

| LINE NO. | REMARKS.  |
|----------|---|
| 332.     | First two units lacking in vigor but others vigorous. Variations may be due to soil.          |
| 388.     | Fourth unit a typical semi-curlydwarf.  |
| 354.     | First unit semi-curlydwarf.   |
| 391.     | A good vigorous type.   |
| 333.     | A good vigorous type.   |
| 390.     | A good vigorous type.   |
| 363.     | A good vigorous type; third unit inclined to semi-curlydwarf.                                 |
| 306.     | First unit curlydwarf; others fairly vigorous.  |
| 372.     | A good vigorous type.   |
| 324.     | A fairly good type; a few weak plants, but these may possibly be due to soil.                 |
| 373.     | Variable as to vigor; some plants with curlydwarf tendencies, though all are fairly vigorous. |
| 343.     | A good vigorous type with exception of first unit.  |
| 362.     | A good vigorous type.   |
| 404.     | A good vigorous type.   |
| 317.     | A good vigorous type.   |
| 338.     | A good vigorous type.   |
| 383.     | A very good type; some variation as to vigor, but this may possibly be due to soil.           |
| 320.     | Vigorous with exception of third unit, which is a typical semi-curlydwarf.                    |
| 330.     | A good vigorous type.   |
| 348.     | Units 1, 4, and 5, very vigorous; other two very good type.                                   |
| 310.     | First unit with curlydwarf tendencies; others very vigorous.                                  |

Of these 22 lines, only 9 were noted as having uniformly good vine characteristics in 1918. Eight contained four or more hills with degenerate tendencies, and 5 showed variations in vigor which possibly might have been attributed to soil but which may, on the other hand, turn out to be the first signs of degeneration. Yield records do not promise to be very effective in dealing with degeneration. It is true that those lines which have appeared frequently among the lowest-yielding are typical degenerates, but degenerate tendencies are also noticeable among the high-yielding ones. On the other hand, 7 of the 19 lines noted with good vine characteristics in 1918 have each appeared once among the low-yielding 20 in Table IV. This indicates that low yields are not always associated with degeneration.

The number of tubers produced in the hill is often suggested as a point worth considering in making seed-potato selections. In Table V will be found a summary of numerical tuber production in the 108 Green Mountain tuber lines. There is a maximum variation in the 3-year averages of 3.45 tubers per single-stemmed hill. The 20 ranking highest in

numerical tuber production (Table VI) have as a group a 3-year average record of 4.04 tubers per hill, while the 20 ranking lowest (Table VII) have averaged for the 3-year period 2.40 tubers per hill. The number of tubers produced in the hills varies from year to year, as will be shown in the yearly averages of the different lines. The 108 Green Mountain lines averaged 1.96 tubers per hill in 1916, 3.97 in 1917, and 2.78 in 1918. Variable soil moisture conditions during the setting period are no doubt responsible for a goodly portion of this fluctuation in tuber production, although delayed thinning may have contributed to the low yields of 1916. In a general way, numerical tuber production and production by weight rise and fall together, but this is by no means a fixed rule. Lines of this variety show the greatest variance in numerical tuber production, but this is no doubt accounted for by the more pronounced degenerate tendencies among a larger proportion of these lines. Degenerate lines do not fall off so much in total number of tubers produced, but a larger proportion of the tubers grade below marketable size. Once degeneration begins in this variety, the line rapidly loses in vitality and yielding power. To illustrate this we might call attention to the record of line 345. This yielded 15,680 pounds per acre in 1916, while the average of all Green Mountain lines for that year was 11,335 pounds. In 1917 it yielded 14,402 pounds as compared with an average of 26,595 for all Green Mountain lines; and in 1918 it yielded 1,366 pounds, as compared with an average of 17,494 for all these lines. Expressed in plus and minus variations, this line yielded 4,345 pounds above the average in 1916, 12,193 below the average in 1917, and 16,127 below the average in 1918.

TABLE V.—Three-year average numerical production of marketable tubers per hill from 108 Green Mountain tuber lines

| Line No. | Yield. | Line No. | Yield. | Line No. | Yield. | Line No. | Yield. |
|----------|--------|----------|--------|----------|--------|----------|--------|
| 300..... | 3.50   | 328..... | 3.12   | 355..... | 3.69   | 382..... | 3.95   |
| 301..... | 3.22   | 329..... | 3.65   | 356..... | 2.79   | 383..... | 4.27   |
| 302..... | 3.22   | 330..... | 4.18   | 357..... | 3.40   | 384..... | 3.95   |
| 304..... | 3.30   | 331..... | 3.29   | 358..... | 2.90   | 385..... | 2.13   |
| 305..... | 2.88   | 332..... | 4.64   | 359..... | 3.04   | 386..... | 3.11   |
| 306..... | 3.74   | 333..... | 4.36   | 360..... | 2.83   | 387..... | 2.72   |
| 307..... | 2.13   | 334..... | 2.75   | 361..... | 3.06   | 388..... | 3.72   |
| 308..... | 2.02   | 335..... | 3.54   | 362..... | 3.84   | 389..... | 2.71   |
| 309..... | 2.95   | 336..... | 3.02   | 363..... | 3.37   | 390..... | 3.63   |
| 310..... | 3.75   | 337..... | 2.79   | 364..... | 3.20   | 391..... | 3.97   |
| 311..... | 3.50   | 338..... | 4.06   | 365..... | 3.45   | 392..... | 2.93   |
| 312..... | 2.88   | 339..... | 2.65   | 366..... | 3.13   | 393..... | 3.20   |
| 313..... | 3.06   | 340..... | 3.21   | 367..... | 3.50   | 394..... | 3.81   |
| 314..... | 3.16   | 341..... | 2.90   | 368..... | 2.57   | 395..... | 3.57   |
| 315..... | 3.11   | 342..... | 3.02   | 369..... | 2.44   | 396..... | 3.93   |
| 316..... | 3.30   | 343..... | 3.84   | 370..... | 2.16   | 397..... | 2.83   |
| 317..... | 3.48   | 344..... | 1.19   | 371..... | 3.11   | 398..... | 3.68   |
| 318..... | 3.34   | 345..... | 1.95   | 372..... | 3.42   | 399..... | 3.36   |
| 319..... | 3.35   | 346..... | 2.95   | 373..... | 4.32   | 400..... | 3.62   |
| 320..... | 3.68   | 347..... | 2.59   | 374..... | 2.70   | 401..... | 3.16   |
| 321..... | 2.78   | 348..... | 3.40   | 375..... | 3.14   | 402..... | 2.40   |
| 322..... | 3.16   | 349..... | 2.56   | 376..... | 4.41   | 403..... | 3.30   |
| 323..... | 3.50   | 350..... | 3.09   | 377..... | 3.53   | 404..... | 4.43   |
| 324..... | 3.75   | 351..... | 3.30   | 378..... | 3.38   | 405..... | 3.23   |
| 325..... | 3.27   | 352..... | 2.87   | 379..... | 2.68   | 406..... | 3.86   |
| 326..... | 3.61   | 353..... | 2.93   | 380..... | 2.78   | 407..... | 2.83   |
| 327..... | 3.43   | 354..... | 3.93   | 381..... | 1.86   | 408..... | 2.30   |

TABLE VI.—Twenty highest-yielding of 108 Green Mountain tuber lines when ranked on 3-year average numerical production of marketable tubers per hill<sup>a</sup>

| Line No.  | Yield. | Line No.  | Yield. | Line No.  | Yield. | Line No.  | Yield. |
|-----------|--------|-----------|--------|-----------|--------|-----------|--------|
| *332..... | 4. 64  | *383..... | 4. 27  | 396.....  | 3. 93  | *362..... | 3. 84  |
| *404..... | 4. 43  | *330..... | 4. 18  | *354..... | 3. 93  | 394.....  | 3. 81  |
| *376..... | 4. 41  | *338..... | 4. 06  | *320..... | 3. 88  | *324..... | 3. 75  |
| *333..... | 4. 36  | *391..... | 3. 97  | 406.....  | 3. 86  | 310.....  | 3. 75  |
| *373..... | 4. 32  | 382.....  | 3. 95  | *343..... | 3. 84  | *306..... | 3. 74  |

<sup>a</sup>The 15 starred lines also appear among the 20 highest-yielding when ranked on the 3-year average production of marketable tubers by weight. Ten of these lines, printed in bold-face type, appear among the 19 lines selected in 1918 as having uniformly good vine characteristics. Average of group, 4.40 tubers per hill.

TABLE VII.—Twenty lowest-yielding of 108 Green Mountain tuber lines when ranked on 3-year average numerical production of marketable tubers per hill<sup>a</sup>

| Line No.  | Yield. | Line No.  | Yield. | Line No.  | Yield. | Line No. | Yield. |
|-----------|--------|-----------|--------|-----------|--------|----------|--------|
| *344..... | 1. 19  | *370..... | 2. 16  | *368..... | 2. 57  | 389..... | 2. 71  |
| *381..... | 1. 86  | *408..... | 2. 30  | *347..... | 2. 59  | 387..... | 2. 72  |
| *345..... | 1. 95  | *402..... | 2. 40  | *339..... | 2. 65  | 334..... | 2. 75  |
| *385..... | 2. 13  | 369.....  | 2. 44  | 379.....  | 2. 68  | 321..... | 2. 78  |
| 397.....  | 2. 13  | *349..... | 2. 50  | *374..... | 2. 70  | 380..... | 2. 78  |

<sup>a</sup>The 12 lines starred also appear among the 20 ranking lowest in weight of marketable tubers. None of these 20 low-yielding lines have good vine characteristics. Average of group, 2.40 tubers per hill.

The 19 lines selected in 1918 as having uniformly good vine characteristics have been grouped in Table VIII. The 1918 average of these 19 lines is 26,260 pounds. In Table IX appear an equal number of the heaviest-yielding lines of 1918, with an average production for the year of 29,267 pounds. The 108 Green Mountain lines gave an average yield of 17,493 pounds in 1918. It will be noted that selection based upon vine characteristics alone came very near isolating the high-yielding lines for that season. The 19 lines appearing in Table VIII have as a group a 3-year average record of 23,270 pounds of marketable tubers per acre. The 19 lines standing highest when ranked on their 3-year average yield of marketable tubers have as a group an average of 25,131 pounds. The variation between the two groups, 1,861 pounds per acre, hardly seems sufficient to repay the labor involved in keeping yield records.

TABLE VIII.—Yields of 19 Green Mountain lines chosen upon vine characteristics alone as the best of the 108 lines of this variety in 1918<sup>a</sup>

| Line No.  | Yield.  | Line No.  | Yield.  | Line No.  | Yield.  | Line No.  | Yield.  |
|-----------|---------|-----------|---------|-----------|---------|-----------|---------|
|           | Pounds. |           | Pounds. |           | Pounds. |           | Pounds. |
| 300.....  | 26, 071 | *338..... | 22, 738 | *372..... | 31, 296 | 394.....  | 20, 074 |
| *317..... | 23, 472 | 340.....  | 24, 262 | 377.....  | 22, 997 | 396.....  | 25, 688 |
| *330..... | 30, 318 | 348.....  | 30, 715 | *383..... | 22, 983 | 400.....  | 29, 269 |
| *332..... | 29, 424 | 355.....  | 20, 293 | *390..... | 28, 362 | *404..... | 22, 713 |
| *333..... | 25, 320 | *362..... | 29, 966 | *391..... | 32, 989 |           |         |

<sup>a</sup>The lines starred appear among the 20 highest-yielding lines when ranked on the 3-year average production by weight of marketable tubers. Average of group, 26,260 pounds per acre.



TABLE IX.—*Nineteen highest-yielding of 108 Green Mountain lines in 1918<sup>a</sup>*

| Line No. | Yield.         | Line No. | Yield.         | Line No. | Yield.         | Line No. | Yield.         |
|----------|----------------|----------|----------------|----------|----------------|----------|----------------|
|          | <i>Pounds.</i> |          | <i>Pounds.</i> |          | <i>Pounds.</i> |          | <i>Pounds.</i> |
| 391..... | 32,986         | 320..... | 30,663         | 306..... | 29,340         | 361..... | 26,714         |
| 372..... | 31,296         | 330..... | 30,318         | 400..... | 29,269         | 310..... | 26,482         |
| 354..... | 31,128         | 376..... | 30,073         | 398..... | 28,572         | 343..... | 26,249         |
| 363..... | 30,807         | 362..... | 29,966         | 390..... | 28,362         | 300..... | 26,017         |
| 348..... | 30,715         | 332..... | 29,424         | 388..... | 27,873         |          |                |

<sup>a</sup> The lines printed in bold-face type also appear in the group with good vine characteristics. This leaves 10 of the 19 lines with vines suggesting degenerate tendencies. Average of group, 29,267 pounds per acre.

## RURAL NEW YORKER TUBER LINES 409 TO 516

Rural New Yorker has ranked very high in the variety tests conducted at this Station. Experience would lead to the belief that, with the possible exception of Russet Burbank, no main crop variety tested in these experiments will give more uniformly satisfactory results upon heavy types of irrigated land. Usually little difficulty is experienced in maintaining good, vigorous stock where the seed is carefully selected after the digger. The average yield of all strains of Rural tested in 1916, 1917, and 1918 was 13,449 pounds of marketable tubers per acre. It will be noted that the average yield of the 108 tuber lines for the same period was 16,820 pounds. The 3-year performance record of these lines is presented in Table X. Here, as well as in Table II, it is interesting to note the variation in the average annual yield of all lines for the three seasons. Within any one season the variation between tuber lines is not so pronounced as it is in Green Mountain; but as yet none of these lines has reached the final stage of degeneration as several Green Mountain lines have. No effort is made to draw conclusions from Table X as a whole, but in Tables XI and XII an effort has been made to present a portion of the data included in Table X in such form that we may get some idea of the value of a 3-year performance record in isolating high-yielding lines.

TABLE X.—*Three-year summary of yields of marketable tubers per acre from 108 Rural New Yorker tuber lines*

| Tuber line No. | 1916           | 1917           | 1918           | 3-year average. |
|----------------|----------------|----------------|----------------|-----------------|
|                | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>  |
| 409.....       | 12,776         | 22,007         | 17,422         | 17,401          |
| 410.....       | 9,872          | 20,907         | 18,351         | 16,376          |
| 411.....       | 9,292          | 22,300         | 22,956         | 18,182          |
| 412.....       | 13,357         | 26,327         | 24,939         | 21,541          |
| 413.....       | 9,292          | 27,876         | 15,648         | 17,605          |
| 414.....       | 9,872          | 23,230         | 26,585         | 19,895          |
| 415.....       | 12,776         | 25,919         | 23,961         | 20,885          |
| 416.....       | 12,776         | 21,371         | 28,108         | 20,751          |
| 417.....       | 8,130          | 24,623         | 22,683         | 18,478          |
| 418.....       | 4,005          | 17,869         | 14,867         | 12,267          |
| 419.....       | 11,034         | 24,159         | 20,442         | 18,545          |
| 420.....       | 7,549          | 24,159         | 20,442         | 17,383          |
| 421.....       | 8,711          | 25,088         | 18,584         | 17,461          |

TABLE X.—Three-year summary of yields of marketable tubers per acre from 108 Rural New Yorker tuber lines—Continued

| Tuber line No. | 1916    | 1917    | 1918    | 3-year average. |
|----------------|---------|---------|---------|-----------------|
|                | Pounds. | Pounds. | Pounds. | Pounds.         |
| 422.....       | 11,615  | 28,340  | 17,190  | 19,048          |
| 423.....       | 12,776  | 23,230  | 14,867  | 16,957          |
| 424.....       | 11,615  | 27,386  | 24,049  | 21,017          |
| 425.....       | 8,711   | 21,836  | 28,362  | 19,636          |
| 426.....       | 8,711   | 24,159  | 21,165  | 18,011          |
| 427.....       | 10,453  | 21,836  | 17,654  | 16,647          |
| 428.....       | 1,742   | 34,070  | 18,351  | 18,054          |
| 429.....       | 7,742   | 22,765  | 16,626  | 15,711          |
| 430.....       | 6,388   | 23,230  | 20,650  | 18,756          |
| 431.....       | 6,388   | 20,946  | 17,551  | 16,961          |
| 432.....       | 9,291   | 25,430  | 15,159  | 16,626          |
| 433.....       | 9,872   | 20,482  | 24,623  | 20,325          |
| 434.....       | 6,969   | 27,031  | 26,714  | 20,238          |
| 435.....       | 7,549   | 23,230  | 21,516  | 17,431          |
| 436.....       | 6,969   | 23,230  | 22,765  | 17,654          |
| 437.....       | 8,130   | 25,088  | 18,119  | 17,112          |
| 438.....       | 6,388   | 21,836  | 18,582  | 15,602          |
| 439.....       | 6,388   | 20,442  | 25,428  | 17,419          |
| 440.....       | 9,292   | 23,230  | 21,371  | 17,964          |
| 441.....       | 6,969   | 22,300  | 20,132  | 16,467          |
| 442.....       | 6,388   | 24,623  | 27,873  | 19,628          |
| 443.....       | 10,453  | 25,088  | 27,876  | 21,139          |
| 444.....       | 10,453  | 19,048  | 17,035  | 15,512          |
| 445.....       | 11,615  | 19,513  | 19,977  | 17,035          |
| 446.....       | 11,613  | 26,482  | 19,745  | 19,280          |
| 447.....       | 9,292   | 16,002  | 21,589  | 15,627          |
| 448.....       | 13,938  | 24,452  | 23,229  | 20,539          |
| 449.....       | 12,776  | 23,694  | 17,422  | 17,964          |
| 450.....       | 12,195  | 23,230  | 25,142  | 20,189          |
| 451.....       | 11,034  | 25,430  | 25,428  | 20,630          |
| 452.....       | 11,034  | 26,017  | 20,648  | 19,233          |
| 453.....       | 6,388   | 26,017  | 13,938  | 15,447          |
| 454.....       | 5,807   | 14,402  | 18,093  | 12,767          |
| 455.....       | 10,453  | 22,765  | 19,048  | 17,422          |
| 456.....       | 11,615  | 13,938  | 17,035  | 14,196          |
| 457.....       | 12,195  | 23,230  | 19,758  | 15,394          |
| 458.....       | 9,292   | 22,300  | 19,071  | 16,887          |
| 459.....       | 9,292   | 22,765  | 17,654  | 16,579          |
| 460.....       | 11,034  | 20,442  | 20,049  | 17,175          |
| 461.....       | 9,292   | 20,907  | 13,473  | 14,557          |
| 462.....       | 10,453  | 24,159  | 19,071  | 17,894          |
| 463.....       | 11,034  | 16,261  | 16,519  | 14,604          |
| 464.....       | 8,711   | 23,230  | 17,035  | 16,325          |
| 465.....       | 8,130   | 19,948  | 24,039  | 17,372          |
| 466.....       | 8,130   | 21,836  | 18,093  | 16,019          |
| 467.....       | 7,549   | 23,694  | 18,093  | 16,445          |
| 468.....       | 5,807   | 19,670  | 13,692  | 13,058          |
| 469.....       | 9,872   | 19,513  | 20,907  | 16,764          |
| 470.....       | 5,807   | 22,300  | 20,538  | 16,215          |
| 471.....       | 5,226   | 19,977  | 18,582  | 14,595          |
| 472.....       | 7,549   | 16,261  | 18,351  | 14,053          |
| 473.....       | 5,807   | 18,119  | 17,359  | 13,761          |
| 474.....       | 7,549   | 19,977  | 17,422  | 14,682          |
| 475.....       | 6,969   | 20,442  | 17,035  | 14,815          |
| 476.....       | 8,130   | 23,694  | 12,544  | 12,621          |
| 477.....       | 5,807   | 19,513  | 18,067  | 16,165          |
| 478.....       | 8,130   | 22,300  | 18,857  | 15,693          |
| 479.....       | 8,711   | 19,513  | 22,300  | 18,697          |
| 480.....       | 10,453  | 23,230  |         |                 |

TABLE X.—Three-year summary of yields of marketable tubers per acre from 108 Rural New Yorker tuber lines—Continued

| Tuber line No. | 1916    | 1917    | 1918    | 3-year average. |
|----------------|---------|---------|---------|-----------------|
|                | Pounds. | Pounds. | Pounds. | Pounds.         |
| 481.....       | 10,453  | 16,725  | 17,935  | 14,737          |
| 482.....       | 11,615  | 18,584  | 20,538  | 16,912          |
| 483.....       | 9,292   | 16,261  | 11,247  | 12,266          |
| 484.....       | 8,711   | 12,195  | 17,551  | 12,819          |
| 485.....       | 11,615  | 20,907  | 18,119  | 16,880          |
| 486.....       | 10,453  | 17,654  | 24,049  | 17,385          |
| 487.....       | 9,292   | 18,119  | 21,371  | 16,260          |
| 488.....       | 5,807   | 19,048  | 19,048  | 14,634          |
| 489.....       | 6,969   | 18,584  | 22,494  | 16,055          |
| 490.....       | 10,453  | 18,584  | 13,692  | 14,243          |
| 491.....       | 11,613  | 22,300  | 17,887  | 17,266          |
| 492.....       | 8,711   | 23,694  | 23,488  | 18,631          |
| 493.....       | 11,615  | 18,584  | 18,826  | 16,341          |
| 494.....       | 9,872   | 20,442  | 16,260  | 15,524          |
| 495.....       | 12,195  | 19,048  | 19,515  | 16,852          |
| 496.....       | 13,938  | 19,513  | 21,700  | 18,403          |
| 497.....       | 10,453  | 23,694  | 20,674  | 18,273          |
| 498.....       | 8,130   | 19,513  | 22,455  | 16,699          |
| 499.....       | 8,130   | 21,029  | 17,190  | 15,449          |
| 500.....       | 4,646   | 22,300  | 14,670  | 13,872          |
| 501.....       | 4,646   | 22,765  | 22,765  | 16,725          |
| 502.....       | 6,969   | 22,765  | 19,977  | 16,570          |
| 503.....       | 6,388   | 20,907  | 19,513  | 15,602          |
| 504.....       | 4,646   | 23,230  | 20,442  | 16,106          |
| 505.....       | 9,872   | 18,584  | 18,093  | 15,516          |
| 506.....       | 4,646   | 24,623  | 20,049  | 16,430          |
| 507.....       | 5,226   | 19,048  | 21,516  | 15,263          |
| 508.....       | 7,549   | 21,371  | 17,115  | 15,345          |
| 509.....       | 8,711   | 21,029  | 12,389  | 14,043          |
| 510.....       | 4,646   | 25,088  | 25,552  | 18,428          |
| 511.....       | 8,711   | 21,836  | 19,560  | 16,702          |
| 512.....       | 6,969   | 22,300  | 19,560  | 16,276          |
| 513.....       | 6,969   | 22,300  | 20,674  | 16,647          |
| 514.....       | 6,969   | 22,300  | 20,442  | 16,570          |
| 515.....       | 9,292   | 22,300  | 17,654  | 16,415          |
| 516.....       | 8,130   | 17,190  | 20,907  | 15,409          |
| Average.....   | 8,831   | 21,864  | 19,787  | 16,820          |

The data included in these tables indicate that with few exceptions high-yielding lines are not consistent high yielders, neither are all low-yielding lines consistent low yielders. The following brief field notes taken in 1918 do not indicate that yield records will be found very satisfactory in dealing with degeneration. For instance, line 448 has a very good performance record. It ranked first in 1916, appeared among the highest-yielding 20 in 1918, only missed by a narrow margin a place among the best 20 in 1917, and ranks seventh according to the 3-year average. But unless the vine characteristics are very deceiving, its yielding power will drop at least 50 per cent during the next two years. One-third of these lines with promising performance records contained some plants with degenerate tendencies. The field notes of 1918 indicate to what extent degeneration appears among the lines that have appeared for at least two out of three years among the 20 highest-yielding or would be ranked with the 20 highest according to the 3-year average.

TABLE XI.—Twenty highest annual rankings and 3-year average rankings from 108 Rural New Yorker tuber lines<sup>a</sup>

| 1918       |                | 1917      |                | 1916     |                | 3-year average. |                |
|------------|----------------|-----------|----------------|----------|----------------|-----------------|----------------|
| Line No.   | Yield.         | Line No.  | Yield.         | Line No. | Yield.         | Line No.        | Yield.         |
|            | <i>Pounds.</i> |           | <i>Pounds.</i> |          | <i>Pounds.</i> |                 | <i>Pounds.</i> |
| *425....   | 28, 362        | *428....  | 34, 070        | *448.... | 13, 938        | ***412....      | 21, 541        |
| **416....  | 28, 108        | **422.... | 28, 341        | *496.... | 13, 938        | **443....       | 21, 139        |
| **443....  | 27, 876        | *413....  | 27, 876        | 412....  | 13, 357        | ***424....      | 21, 017        |
| **442....  | 27, 873        | 424....   | 27, 387        | *475.... | 12, 777        | ***415....      | 20, 885        |
| **434....  | 26, 714        | *434....  | 27, 031        | *449.... | 12, 777        | *416....        | 20, 751        |
| *430....   | 26, 650        | *431....  | 26, 947        | *423.... | 12, 777        | **451....       | 20, 630        |
| *414....   | 26, 585        | 433....   | 26, 482        | 416....  | 12, 777        | **448....       | 20, 539        |
| **510....  | 25, 552        | **446.... | 26, 482        | *409.... | 12, 777        | **433....       | 20, 325        |
| *451....   | 25, 428        | 412....   | 26, 327        | *495.... | 12, 190        | **434....       | 20, 238        |
| *439....   | 25, 438        | *453....  | 26, 081        | *457.... | 12, 190        | **450....       | 20, 189        |
| *450....   | 25, 142        | *452....  | 26, 081        | 450....  | 12, 190        | *414....        | 19, 895        |
| **405....  | 24, 939        | 415....   | 25, 920        | 424....  | 11, 615        | *425....        | 19, 636        |
| ***412.... | 24, 939        | 451....   | 25, 430        | *422.... | 11, 615        | **442....       | 19, 628        |
| **433....  | 24, 623        | *432....  | 25, 430        | *493.... | 11, 615        | **446....       | 19, 280        |
| ***424.... | 24, 049        | 510....   | 25, 088        | *485.... | 11, 615        | *452....        | 19, 233        |
| *486....   | 24, 049        | 443....   | 25, 088        | *482.... | 11, 615        | **422....       | 19, 048        |
| ***415.... | 23, 961        | *437....  | 25, 088        | *456.... | 11, 615        | *430....        | 18, 756        |
| *492....   | 23, 488        | *421....  | 25, 088        | *455.... | 11, 615        | *480....        | 18, 697        |
| **448....  | 23, 229        | 442....   | 24, 624        | 446....  | 11, 614        | *492....        | 18, 031        |
| *411....   | 22, 956        | *506....  | 24, 624        | *491.... | 11, 614        | 419....         | 18, 545        |
|            |                | *417....  | 24, 624        |          |                |                 |                |

<sup>a</sup> The number of stars indicates how many times the line has appeared among the 25 highest rankings. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. Three lines appear three times, 11 lines appear twice, and 32 lines appear only once.

TABLE XII.—Twenty lowest annual rankings and 3-year average rankings from 108 Rural New Yorker tuber lines<sup>a</sup>

| 1918       |                | 1917      |                | 1916     |                | 3-year average. |                |
|------------|----------------|-----------|----------------|----------|----------------|-----------------|----------------|
| Line No.   | Yield.         | Line No.  | Yield.         | Line No. | Yield.         | Line No.        | Yield.         |
|            | <i>Pounds.</i> |           | <i>Pounds.</i> |          | <i>Pounds.</i> |                 | <i>Pounds.</i> |
| *457....   | 10, 758        | *484....  | 12, 196        | *428.... | 1, 742         | **483....       | 12, 266        |
| **483....  | 11, 247        | 456....   | 13, 938        | 418....  | 4, 065         | ***418....      | 12, 267        |
| *509....   | 12, 389        | *454....  | 14, 493        | *506.... | 4, 646         | **477....       | 12, 621        |
| **477....  | 12, 544        | *447....  | 16, 093        | *510.... | 4, 646         | *454....        | 12, 767        |
| *461....   | 13, 473        | *472....  | 16, 261        | *504.... | 4, 646         | *484....        | 12, 819        |
| **468....  | 13, 692        | 463....   | 16, 261        | *501.... | 4, 646         | **468....       | 13, 058        |
| **490....  | 13, 692        | 483....   | 16, 261        | 500....  | 4, 646         | **473....       | 13, 791        |
| **453....  | 13, 938        | 481....   | 16, 726        | *507.... | 5, 227         | *500....        | 13, 872        |
| ***500.... | 14, 670        | *516....  | 17, 190        | *471.... | 5, 227         | *509....        | 14, 043        |
| ***418.... | 14, 867        | *486....  | 17, 665        | 473....  | 5, 808         | *472....        | 14, 033        |
| *423....   | 14, 867        | 418....   | 17, 869        | *450.... | 5, 808         | **456....       | 14, 196        |
| *432....   | 15, 159        | **473.... | 18, 119        | 468....  | 5, 808         | **490....       | 14, 243        |
| *413....   | 15, 648        | *487....  | 18, 119        | 477....  | 5, 808         | *461....        | 14, 557        |
| *494....   | 16, 260        | *489....  | 18, 584        | *488.... | 5, 808         | *471....        | 14, 595        |
| *403....   | 16, 519        | 490....   | 18, 584        | *470.... | 5, 808         | **493....       | 14, 604        |
| *429....   | 16, 626        | *505....  | 18, 584        | *442.... | 6, 388         | **488....       | 14, 634        |
| **481....  | 17, 035        | *482....  | 18, 584        | 453....  | 6, 388         | *481....        | 14, 737        |
| *464....   | 17, 035        | *493....  | 18, 584        | *431.... | 6, 388         | *475....        | 14, 815        |
| *475....   | 17, 035        | *495....  | 19, 049        | *503.... | 6, 388         | 474....         | 14, 982        |
| *456....   | 17, 035        | **468.... | 19, 049        | *439.... | 6, 388         | **507....       | 15, 262        |
| *444....   | 17, 035        | 444....   | 19, 049        | *430.... | 6, 388         |                 |                |
|            |                | *405....  | 19, 049        | *438.... | 6, 388         |                 |                |
|            |                | **507.... | 19, 049        |          |                |                 |                |

<sup>a</sup> The number of stars indicates how many times the line has appeared among the 20 lowest rankings. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. One appears three times, 13 lines appear twice, and 37 lines appear only once.

Of these 21 lines, 7 have curlydwarf tendencies. Twelve appear among the best 33 lines chosen in 1918 on vine characteristics alone. This leaves two, 443 and 452, in the doubtful list.

| LINE NO. | REMARKS.   |
|----------|--|
| 416.     | Third unit a curlydwarf; others vigorous though lacking in uniformity. |
| 443.     | A very good type; first and second unit not especially vigorous.       |
| 442.     | A good vigorous type.  |
| 434.     | A good vigorous type.  |
| 510.     | A good vigorous type.  |
| 451.     | A good vigorous type.  |
| 450.     | Not a very good type.  |
| 412.     | Uniform and fairly vigorous.   |
| 433.     | A good vigorous type.  |
| 424.     | Vines not a good type.   |
| 415.     | A good type and fairly vigorous.                                       |
| 448.     | All have more or less curlydwarf tendency.                             |
| 422.     | Lacking in vigor but type good.  |
| 446.     | First four units have curlydwarf tendencies.                           |
| 414.     | First unit with curlydwarf tendencies.                                 |
| 425.     | Very good and vigorous type.   |
| 452.     | Not very vigorous but type good.                                       |
| 430.     | First unit very vigorous; others good.                                 |
| 480.     | Fairly vigorous.   |
| 492.     | A very good type.  |
| 419.     | Some curlydwarf tendencies.  |

In Table XIII data are presented showing the 3-year average numerical production of tubers per single-stemmed hill. In Tables XIV and XV a portion of this data is used to show the lack of correlation between yields in numbers and in weight, as well as the relation between numerical tuber production and good vine characteristics. There is in Table XIII a maximum variation of 1.29 tubers per hill. Between the average of the 20 highest and 20 lowest (Tables XIV and XV) there is a variation of 0.79 tubers per hill. Considering that these are single-stemmed hills, this variation is rather pronounced. But the data are apparently no more reliable than weight records in pointing out promising lines. Low numerical tuber production does not always mean low production by weight, and such records are apparently of little value as a check on degenerate tendencies. Fluctuation in tuber production in different seasons has been even greater than the variation between lines in any one season. These 108 lines averaged 2.05 marketable tubers per hill in 1916, 3.78 in 1917, and 2.44 in 1918.

In Table XVI the 33 lines with promising vine characteristics have been assembled with their 1918 yields of marketable tubers. The average yield of these 33 lines is 21,142 pounds per acre. In Table XVII the 33 heaviest-yielding lines of 1918 are assembled for comparison. Their average yield is 24,109 pounds, while the 1918 average of the 108 Rural New Yorker lines was 19,787 pounds per acre. The lines chosen upon vine

characteristics alone yielded well above the average of the 108 lines but did not equal the 33 heaviest-yielding lines of 1918. Field notes show that 15 of these heavy-yielding lines of 1918 have poor vine characteristics. This means that if mass selection based on tuber characteristics is practiced within these 15 lines their progeny will be almost certain to contain some rather advanced degenerate types that will materially decrease the yield of the lines in 1919. On the other hand, we can be almost sure that no well-advanced or low-yielding degenerates will appear among the 1919 progeny of those with good 1918 vine characteristics. It is interesting to go back beyond the 1918 records and compare the 3-year performance of these lines assembled in Table XVI with the 33 highest-yielding Rural New Yorker lines when ranked upon their 3-year average production. The 33 lines in Table XVI have produced during the 3-year period an average yield of 17,740 pounds per acre. The 33 of the 108 Rural New Yorker lines ranking highest according to the 3-year average production by weight have yielded on an average 19,181 pounds. Between the two groups there is a variation of 1,441 pounds in favor of the 33 lines ranked upon their performance record. But when vine development so nearly foretells the yielding power of the line it would really seem that this is a more practical basis for selection than yields measured in either weight or number of tubers.

TABLE XIII.—Three-year average numerical production of marketable tubers per hill from 108 rural New Yorker tuber lines

| Line No. | Yield. | Line No. | Yield. | Line No. | Yield. | Line No. | Yield. |
|----------|--------|----------|--------|----------|--------|----------|--------|
| 409..... | 3.30   | 436..... | 3.29   | 463..... | 3.00   | 490..... | 2.76   |
| 410..... | 3.47   | 437..... | 3.02   | 464..... | 3.07   | 491..... | 2.79   |
| 411..... | 3.65   | 438..... | 3.18   | 465..... | 3.02   | 492..... | 3.16   |
| 412..... | 3.34   | 439..... | 3.00   | 466..... | 2.90   | 493..... | 2.83   |
| 413..... | 3.25   | 440..... | 2.95   | 467..... | 3.04   | 494..... | 2.69   |
| 414..... | 2.80   | 441..... | 3.19   | 468..... | 2.60   | 495..... | 2.93   |
| 415..... | 3.19   | 442..... | 3.48   | 469..... | 3.10   | 496..... | 2.83   |
| 416..... | 3.31   | 443..... | 2.68   | 470..... | 3.04   | 497..... | 3.25   |
| 417..... | 2.97   | 444..... | 3.04   | 471..... | 2.65   | 498..... | 2.78   |
| 418..... | 2.86   | 445..... | 3.09   | 472..... | 3.06   | 499..... | 2.79   |
| 419..... | 3.63   | 446..... | 3.32   | 473..... | 3.11   | 500..... | 2.83   |
| 420..... | 3.54   | 447..... | 3.10   | 474..... | 3.06   | 501..... | 3.29   |
| 421..... | 3.34   | 448..... | 3.07   | 475..... | 3.02   | 502..... | 3.06   |
| 422..... | 3.56   | 449..... | 2.88   | 476..... | 2.77   | 503..... | 2.72   |
| 423..... | 2.97   | 450..... | 3.04   | 477..... | 2.95   | 504..... | 2.93   |
| 424..... | 3.15   | 451..... | 3.21   | 478..... | 3.16   | 505..... | 2.64   |
| 425..... | 3.53   | 452..... | 3.38   | 479..... | 3.21   | 506..... | 3.60   |
| 426..... | 3.59   | 453..... | 3.20   | 480..... | 3.04   | 507..... | 3.27   |
| 427..... | 3.00   | 454..... | 2.03   | 481..... | 3.02   | 508..... | 2.74   |
| 428..... | 2.55   | 455..... | 2.81   | 482..... | 2.95   | 509..... | 2.60   |
| 429..... | 3.20   | 456..... | 2.78   | 483..... | 2.55   | 510..... | 3.19   |
| 430..... | 3.41   | 457..... | 2.86   | 484..... | 2.92   | 511..... | 3.11   |
| 431..... | 3.28   | 458..... | 3.04   | 485..... | 2.95   | 512..... | 3.09   |
| 432..... | 3.48   | 459..... | 3.29   | 486..... | 3.19   | 513..... | 3.43   |
| 433..... | 3.43   | 460..... | 3.16   | 487..... | 2.88   | 514..... | 2.75   |
| 434..... | 3.74   | 461..... | 2.70   | 488..... | 2.93   | 515..... | 2.79   |
| 435..... | 3.25   | 462..... | 2.90   | 489..... | 3.02   | 516..... | 2.45   |

TABLE XIV.—Twenty highest-yielding of 108 Rural New Yorker tuber lines when ranked on 3-year average numerical production of marketable tubers per hill<sup>a</sup>

| Line No.   | Yield. | Line No.   | Yield. | Line No.   | Yield. | Line No.   | Yield. |
|------------|--------|------------|--------|------------|--------|------------|--------|
| *434 ..... | 3. 74  | *422 ..... | 3. 56  | 410 .....  | 3. 47  | *412 ..... | 3. 34  |
| 411 .....  | 3. 65  | 420 .....  | 3. 54  | *433 ..... | 3. 43  | 421 .....  | 3. 34  |
| *419 ..... | 3. 63  | *425 ..... | 3. 53  | 513 .....  | 3. 43  | *446 ..... | 3. 32  |
| 506 .....  | 3. 60  | 432 .....  | 3. 48  | *430 ..... | 3. 41  | *416 ..... | 3. 31  |
| 426 .....  | 3. 59  | *442 ..... | 3. 48  | *452 ..... | 3. 38  | 409 .....  | 3. 30  |

<sup>a</sup> The 21 lines starred appear among the 20 highest when ranked on 3-year average production by weight of marketable tubers. Nine of these lines (printed in bold-face type) have uniformly good vine characteristics, and the other 11 have vine characteristics which suggest degeneration. Average of group, 3.47 tubers per hill.

TABLE XV.—Twenty lowest-yielding of 108 Rural New Yorker tuber lines when ranked on 3-year average numerical production of marketable tubers per hill<sup>a</sup>

| Line No.   | Yield. | Line No.   | Yield. | Line No.   | Yield. | Line No.   | Yield. |
|------------|--------|------------|--------|------------|--------|------------|--------|
| 516 .....  | 2. 45  | 505 .....  | 2. 64  | 503 .....  | 2. 72  | *456 ..... | 2. 78  |
| *483 ..... | 2. 55  | *471 ..... | 2. 65  | 508 .....  | 2. 74  | 498 .....  | 2. 78  |
| 428 .....  | 2. 55  | 443 .....  | 2. 68  | 514 .....  | 2. 75  | 491 .....  | 2. 79  |
| *509 ..... | 2. 60  | 494 .....  | 2. 69  | *490 ..... | 2. 76  | 499 .....  | 2. 79  |
| *468 ..... | 2. 60  | *461 ..... | 2. 70  | 476 .....  | 2. 77  | 515 .....  | 2. 79  |

<sup>a</sup> The 7 lines starred appear among the 20 lowest when ranked on 3-year average production by weight of marketable tubers. The 6 lines printed in bold-face type appeared among the 33 chosen in 1918 as having the best vine characteristics, and these 6 have very good 3-year averages for tuber production by weight. Line 248 appeared among the heaviest-yielding 20 in 1918 and only missed by a small margin a place among the 20 heaviest-yielding when ranked on 3-year average production. Average of group, 2.68 tubers per hill.

TABLE XVI.—Yields for 1918 of 33 Rural New Yorker lines chosen upon 1918 vine characteristics alone as the best of the 108 lines of this variety<sup>a</sup>

| Line No.   | Yield.         | Line No.   | Yield.         | Line No.   | Yield.         | Line No.   | Yield.         |
|------------|----------------|------------|----------------|------------|----------------|------------|----------------|
|            | <i>Pounds.</i> |            | <i>Pounds.</i> |            | <i>Pounds.</i> |            | <i>Pounds.</i> |
| *412 ..... | 24, 939        | *442 ..... | 27, 873        | *492 ..... | 23, 488        | 504 .....  | 20, 442        |
| *413 ..... | 15, 648        | *451 ..... | 25, 428        | 493 .....  | 18, 826        | 506 .....  | 20, 049        |
| *415 ..... | 23, 901        | 465 .....  | 24, 939        | 495 .....  | 19, 315        | 507 .....  | 21, 516        |
| *422 ..... | 17, 190        | *480 ..... | 22, 409        | *496 ..... | 21, 760        | 508 .....  | 17, 115        |
| *425 ..... | 28, 362        | 486 .....  | 24, 049        | *497 ..... | 20, 674        | *510 ..... | 25, 552        |
| *428 ..... | 18, 351        | 488 .....  | 19, 048        | 498 .....  | 22, 455        | 513 .....  | 20, 674        |
| *430 ..... | 26, 650        | 489 .....  | 22, 494        | 501 .....  | 22, 765        | 514 .....  | 20, 442        |
| *433 ..... | 24, 623        | 491 .....  | 17, 887        | 503 .....  | 19, 513        | 516 .....  | 20, 907        |
| *434 ..... | 26, 714        |            |                |            |                |            |                |

<sup>a</sup> The 16 lines starred appear among the 33 highest-yielding lines when ranked on their 3-year average record. Lines 488 and 507 rank among the 20 lowest-yielding according to the 3-year average. Average of group, 21,142 pounds per acre.

TABLE XVII.—Thirty-three highest-yielding lines of 108 Rural New Yorker tuber lines in 1918<sup>a</sup>

| Line No.  | Yield.         | Line No.  | Yield.         | Line No.  | Yield.         | Line No.  | Yield.         |
|-----------|----------------|-----------|----------------|-----------|----------------|-----------|----------------|
|           | <i>Pounds.</i> |           | <i>Pounds.</i> |           | <i>Pounds.</i> |           | <i>Pounds.</i> |
| 425 ..... | 28, 362        | 451 ..... | 25, 428        | 492 ..... | 23, 488        | 480 ..... | 22, 409        |
| 416 ..... | 28, 108        | 450 ..... | 25, 1142       | 448 ..... | 23, 229        | 496 ..... | 21, 760        |
| 443 ..... | 27, 876        | 412 ..... | 24, 939        | 411 ..... | 22, 956        | 447 ..... | 21, 589        |
| 442 ..... | 27, 873        | 465 ..... | 24, 939        | 436 ..... | 22, 765        | 435 ..... | 21, 516        |
| 434 ..... | 26, 714        | 433 ..... | 24, 623        | 501 ..... | 22, 765        | 507 ..... | 21, 516        |
| 430 ..... | 26, 650        | 424 ..... | 24, 049        | 417 ..... | 22, 683        | 440 ..... | 21, 371        |
| 414 ..... | 26, 585        | 486 ..... | 24, 049        | 489 ..... | 22, 494        | 487 ..... | 21, 371        |
| 510 ..... | 25, 552        | 415 ..... | 23, 961        | 498 ..... | 22, 455        | 426 ..... | 21, 156        |
| 439 ..... | 25, 428        |           |                |           |                |           |                |

<sup>a</sup> The 18 lines printed in bold-face type appear in Table XVI. This means that of the 33 highest-yielding Rural New Yorker lines in 1918, 15 have poor vine characteristics. Average of group, 24,109 pounds per acre.

## EARLY SIX WEEKS TUBER LINES 517 TO 622

While these lines were selected from stock being grown under the name of Early Six Weeks, they all seem more typical of Red Early Ohio. At first a mixture of Early Ohio and Early Six Weeks was suspected, but observations on vine characteristics have led to the belief that the less vigorous lines, more typical of Early Six Weeks, are nothing more than degenerate types of Early Ohio. Such types are constantly appearing within vigorous dark green lines typical of Early Ohio. With this explanation I will still refer to these as Early Six Weeks lines. Varieties of the Early Ohio types have proved very satisfactory under soil and climatic conditions at the Station, yielding much better than other standard early varieties like Irish Cobbler and Early Triumph, and with less tendency to degeneration.

The 3-year performance record of these 100 lines is presented in Table XVIII. The average annual yield has followed about the same curve as in the other two varieties. There has apparently been ample variation between lines in any one season and in the 3-year average to furnish a basis for selection. As in the other varieties, however, these variations in yield have in many cases been rather inconsistent.

TABLE XVIII.—Three-year summary of yields of marketable tubers per acre from 100 Early Six Weeks tuber lines

| Tuber line No. | 1916           | 1917           | 1918           | 3-year average. |
|----------------|----------------|----------------|----------------|-----------------|
|                | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>  |
| 517.....       | 15,009         | 20,907         | 19,513         | 18,506          |
| 518.....       | 16,261         | 21,681         | 8,802          | 15,581          |
| 519.....       | 10,453         | 24,159         | 17,654         | 17,422          |
| 520.....       | 9,872          | 24,004         | 11,247         | 15,041          |
| 522.....       | 12,195         | 28,340         | 19,804         | 20,113          |
| 523.....       | 12,195         | 20,907         | 13,692         | 15,598          |
| 524.....       | 13,357         | 21,371         | 13,008         | 15,912          |
| 525.....       | 14,518         | 16,958         | 21,271         | 17,582          |
| 526.....       | 12,776         | 23,230         | 20,293         | 18,766          |
| 527.....       | 13,357         | 19,977         | 11,150         | 14,828          |
| 528.....       | 11,615         | 22,300         | 12,469         | 15,461          |
| 529.....       | 13,938         | 26,482         | 18,351         | 19,590          |
| 530.....       | 15,099         | 22,705         | 15,099         | 17,654          |
| 531.....       | 12,776         | 27,565         | 22,713         | 21,018          |
| 532.....       | 16,261         | 22,997         | 18,584         | 19,280          |
| 533.....       | 16,261         | 25,320         | 21,271         | 20,950          |
| 534.....       | 11,615         | 14,402         | 15,099         | 13,705          |
| 535.....       | 6,969          | 22,765         | 16,725         | 15,486          |
| 536.....       | 8,711          | 25,088         | 18,119         | 17,306          |
| 537.....       | 11,615         | 22,300         | 15,331         | 16,415          |
| 538.....       | 9,292          | 19,977         | 11,615         | 13,628          |
| 539.....       | 7,549          | 21,830         | 19,048         | 16,144          |
| 540.....       | 8,711          | 24,159         | 19,977         | 17,615          |
| 541.....       | 11,615         | 22,705         | 21,603         | 18,601          |
| 542.....       | 9,292          | 20,648         | 18,119         | 16,019          |
| 543.....       | 12,776         | 18,351         | 22,300         | 17,809          |
| 545.....       | 6,969          | 17,654         | 7,652          | 10,758          |
| 546.....       | 9,872          | 25,088         | 22,705         | 19,368          |
| 547.....       | 9,292          | 24,624         | 13,473         | 15,796          |
| 548.....       | 11,034         | 29,017         | 25,320         | 20,790          |



TABLE XVIII.—Three-year summary of yields of marketable tubers per acre from 100 Early Six Weeks tuber lines—Continued

| Tuber line No. | 1916           | 1917           | 1918           | 3-year average. |
|----------------|----------------|----------------|----------------|-----------------|
|                | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i>  |
| 549.....       | 13, 938        | 25, 533        | 24, 391        | 21, 294         |
| 550.....       | 12, 195        | 21, 528        | 19, 745        | 17, 822         |
| 551.....       | 19, 745        | 24, 623        | 25, 553        | 23, 307         |
| 552.....       | 17, 422        | 25, 088        | 25, 553        | 22, 687         |
| 553.....       | 10, 453        | 14, 228        | 14, 181        | 12, 954         |
| 554.....       | 9, 872         | 25, 553        | 20, 907        | 18, 777         |
| 555.....       | 9, 292         | 19, 745        | 13, 930        | 14, 324         |
| 556.....       | 13, 357        | 20, 540        | 15, 099        | 16, 332         |
| 558.....       | 12, 195        | 26, 186        | 20, 049        | 19, 476         |
| 559.....       | 8, 711         | 17, 654        | 17, 887        | 14, 750         |
| 560.....       | 12, 776        | 17, 422        | 20, 538        | 16, 912         |
| 561.....       | 9, 292         | 20, 442        | 29, 502        | 19, 745         |
| 562.....       | 12, 776        | 19, 978        | 27, 873        | 20, 209         |
| 563.....       | 15, 099        | 13, 473        | 12, 958        | 13, 843         |
| 564.....       | 11, 034        | 23, 694        | 19, 048        | 17, 925         |
| 565.....       | 15, 680        | 23, 229        | 20, 907        | 19, 938         |
| 566.....       | 11, 034        | 19, 745        | 13, 203        | 14, 660         |
| 568.....       | 11, 615        | 37, 942        | 14, 634        | 21, 397         |
| 569.....       | 15, 680        | 16, 725        | 20, 210        | 17, 538         |
| 570.....       | 12, 195        | 18, 584        | 15, 648        | 15, 475         |
| 571.....       | 10, 453        | 18, 816        | 21, 139        | 16, 802         |
| 572.....       | 12, 776        | 22, 300        | 18, 351        | 17, 809         |
| 573.....       | 9, 292         | 15, 331        | 15, 564        | 13, 395         |
| 574.....       | 8, 130         | 21, 836        | 16, 028        | 15, 331         |
| 575.....       | 10, 453        | 21, 139        | 19, 977        | 17, 189         |
| 576.....       | 10, 453        | 17, 190        | 14, 402        | 14, 015         |
| 577.....       | 17, 422        | 26, 017        | 19, 513        | 20, 984         |
| 578.....       | 15, 099        | 20, 907        | 13, 241        | 16, 415         |
| 579.....       | 14, 518        | 21, 371        | 14, 181        | 16, 090         |
| 580.....       | 15, 099        | 23, 694        | 21, 271        | 20, 021         |
| 581.....       | 13, 938        | 22, 300        | 16, 397        | 17, 545         |
| 582.....       | 12, 776        | 24, 452        | 13, 241        | 16, 823         |
| 583.....       | 14, 518        | 25, 553        | 10, 918        | 16, 996         |
| 584.....       | 14, 518        | 33, 683        | 19, 071        | 22, 424         |
| 585.....       | 9, 292         | 32, 986        | 19, 048        | 20, 442         |
| 586.....       | 12, 195        | 26, 017        | 20, 210        | 19, 474         |
| 588.....       | 12, 195        | 28, 908        | 14, 425        | 18, 509         |
| 589.....       | 15, 099        | 31, 360        | 20, 132        | 22, 197         |
| 590.....       | 10, 453        | 23, 230        | 16, 028        | 16, 570         |
| 591.....       | 12, 776        | 24, 159        | 20, 907        | 19, 280         |
| 592.....       | 13, 938        | 24, 623        | 9, 524         | 16, 028         |
| 593.....       | 14, 518        | 28, 968        | 13, 938        | 19, 141         |
| 594.....       | 15, 099        | 26, 548        | 17, 654        | 19, 767         |
| 595.....       | 12, 195        | 30, 663        | 21, 027        | 21, 295         |
| 596.....       | 14, 518        | 30, 199        | 17, 359        | 20, 692         |
| 597.....       | 11, 615        | 28, 340        | 13, 473        | 17, 809         |
| 599.....       | 11, 615        | 25, 088        | 10, 685        | 15, 796         |
| 600.....       | 10, 453        | 26, 017        | 17, 654        | 18, 041         |
| 601.....       | 7, 549         | 27, 876        | 19, 048        | 18, 157         |
| 602.....       | 11, 615        | 25, 533        | 10, 513        | 15, 887         |
| 603.....       | 15, 099        | 28, 853        | 16, 870        | 20, 274         |
| 604.....       | 12, 195        | 30, 810        | 21, 516        | 21, 507         |
| 605.....       | 14, 518        | 29, 343        | 20, 442        | 21, 434         |
| 606.....       | 13, 357        | 28, 340        | 15, 403        | 19, 033         |
| 607.....       | 13, 938        | 29, 966        | 18, 584        | 20, 829         |
| 608.....       | 11, 615        | 30, 199        | 22, 005        | 21, 273         |
| 609.....       | 9, 292         | 29, 734        | 21, 516        | 20, 180         |
| 610.....       | 11, 615        | 27, 876        | 16, 261        | 18, 584         |
| 611.....       | 13, 938        | 24, 623        | 11, 615        | 16, 725         |

TABLE XVIII.—Three-year summary of yields of marketable tubers per acre from 100 Early Six Weeks tuber lines—Continued

| Tuber line No. | 1916    | 1917    | 1918    | 3-year average. |
|----------------|---------|---------|---------|-----------------|
|                | Pounds. | Pounds. | Pounds. | Pounds.         |
| 612.....       | 15, 099 | 29, 734 | 15, 331 | 20, 054         |
| 613.....       | 12, 195 | 25, 088 | 16, 137 | 17, 806         |
| 614.....       | 15, 099 | 29, 269 | 18, 584 | 20, 984         |
| 615.....       | 11, 034 | 25, 088 | 13, 473 | 16, 531         |
| 616.....       | 13, 938 | 25, 919 | 12, 544 | 17, 407         |
| 617.....       | 13, 938 | 27, 876 | 18, 582 | 20, 132         |
| 618.....       | 15, 099 | 30, 663 | 19, 048 | 21, 603         |
| 619.....       | 9, 292  | 25, 088 | 15, 564 | 16, 648         |
| 620.....       | 11, 034 | 21, 518 | 18, 119 | 16, 890         |
| 621.....       | 8, 711  | 16, 725 | 4, 646  | 10, 027         |
| 622.....       | 12, 195 | 26, 485 | 19, 358 | 19, 345         |
| Average.....   | 12, 334 | 24, 048 | 17, 344 | 17, 909         |

TABLE XIX.—Twenty highest annual rankings and 3-year average rankings from 100 Early Six Weeks tuber lines<sup>a</sup>

| 1918       |         | 1917       |         | 1916      |         | 3-year average. |         |
|------------|---------|------------|---------|-----------|---------|-----------------|---------|
| Line No.   | Yield.  | Line No.   | Yield.  | Line No.  | Yield.  | Line No.        | Yield.  |
|            | Pounds. |            | Pounds. |           | Pounds. |                 | Pounds. |
| *561.....  | 29, 502 | *568.....  | 37, 942 | 551.....  | 10, 746 | **551.....      | 23, 307 |
| *562.....  | 27, 873 | **584..... | 33, 684 | 552.....  | 17, 423 | **552.....      | 22, 687 |
| **552..... | 25, 553 | *585.....  | 32, 987 | *577..... | 17, 423 | *584.....       | 22, 424 |
| **551..... | 25, 553 | **589..... | 31, 361 | *518..... | 16, 261 | *589.....       | 22, 197 |
| *548.....  | 25, 320 | 604.....   | 30, 810 | *532..... | 16, 261 | *618.....       | 21, 603 |
| *549.....  | 24, 391 | *595.....  | 30, 663 | 533.....  | 16, 261 | *604.....       | 21, 507 |
| *546.....  | 22, 705 | *618.....  | 30, 663 | 505.....  | 15, 680 | *605.....       | 21, 434 |
| *531.....  | 22, 713 | 608.....   | 30, 119 | *509..... | 15, 680 | *568.....       | 21, 397 |
| *543.....  | 22, 300 | **596..... | 30, 119 | *578..... | 15, 099 | *595.....       | 21, 295 |
| **608..... | 22, 005 | *607.....  | 29, 066 | 580.....  | 15, 099 | *549.....       | 21, 294 |
| *541.....  | 21, 603 | 609.....   | 29, 734 | *594..... | 15, 099 | *608.....       | 21, 273 |
| **609..... | 21, 516 | **612..... | 29, 734 | 589.....  | 15, 099 | *531.....       | 21, 018 |
| **604..... | 21, 516 | *605.....  | 29, 343 | 618.....  | 15, 099 | *614.....       | 20, 984 |
| *580.....  | 21, 271 | **614..... | 29, 269 | 612.....  | 15, 099 | *577.....       | 20, 984 |
| **525..... | 21, 271 | *593.....  | 28, 969 | 614.....  | 15, 099 | *533.....       | 20, 950 |
| *533.....  | 21, 271 | *588.....  | 28, 908 | 603.....  | 15, 099 | *607.....       | 20, 829 |
| *571.....  | 21, 139 | *603.....  | 28, 854 | *563..... | 15, 099 | *548.....       | 20, 790 |
| *595.....  | 21, 027 | *606.....  | 28, 341 | *530..... | 15, 099 | *606.....       | 20, 692 |
| *591.....  | 20, 907 | *597.....  | 28, 340 | *517..... | 15, 099 | *585.....       | 20, 442 |
| **565..... | 20, 907 | *522.....  | 28, 340 | *583..... | 14, 518 | *603.....       | 20, 274 |
| *554.....  | 20, 907 |            |         | 525.....  | 14, 518 |                 |         |
|            |         |            |         | *579..... | 14, 518 |                 |         |
|            |         |            |         | 584.....  | 14, 518 |                 |         |
|            |         |            |         | 593.....  | 14, 518 |                 |         |
|            |         |            |         | 596.....  | 14, 518 |                 |         |
|            |         |            |         | 605.....  | 14, 518 |                 |         |

<sup>a</sup>The number of stars indicates how many times the line has appeared among the 20 highest rankings. Lines not starred in columns 3 and 5 appear and are starred elsewhere in the table. None appear three times, 18 appear twice, and 31 appear only once.

In Tables XIX and XX a portion of the data from Table XVIII is assembled for the purpose of a more critical study of the performance of the highest-yielding and lowest-yielding 20 of the 100 lines.

TABLE XX.—Twenty lowest annual rankings and 3-year average rankings from 108 Early Six Weeks tuber lines<sup>a</sup>

| 1918     |                | 1917     |                | 1916     |                | 3-year average. |                |
|----------|----------------|----------|----------------|----------|----------------|-----------------|----------------|
| Line No. | Yield.         | Line No. | Yield.         | Line No. | Yield.         | Line No.        | Yield.         |
|          | <i>Pounds.</i> |          | <i>Pounds.</i> |          | <i>Pounds.</i> |                 | <i>Pounds.</i> |
| ***621   | 4, 646         | 563      | 13, 473        | *535     | 6, 969         | ***621          | 10, 027        |
| ***545   | 7, 652         | *553     | 14, 228        | 545      | 6, 969         | ***545          | 10, 758        |
| *518     | 8, 802         | *534     | 14, 402        | *601     | 7, 550         | *553            | 12, 954        |
| *592     | 9, 524         | **573    | 15, 332        | *539     | 7, 550         | **573           | 13, 395        |
| *602     | 10, 513        | *509     | 16, 725        | *574     | 8, 131         | ***538          | 13, 628        |
| *599     | 10, 685        | 621      | 16, 726        | *536     | 8, 711         | *534            | 13, 705        |
| *583     | 10, 918        | *525     | 16, 958        | *540     | 8, 711         | **563           | 13, 843        |
| *527     | 11, 150        | *576     | 17, 190        | 621      | 8, 711         | *576            | 14, 015        |
| **520    | 11, 247        | *560     | 17, 422        | 559      | 8, 711         | **555           | 14, 324        |
| *611     | 11, 615        | **559    | 17, 654        | 538      | 9, 292         | **566           | 14, 660        |
| ***538   | 11, 615        | 545      | 17, 654        | 555      | 9, 292         | **559           | 14, 750        |
| *528     | 12, 469        | *543     | 18, 351        | 573      | 9, 292         | *527            | 14, 828        |
| *616     | 12, 544        | *570     | 18, 584        | 561      | 9, 292         | **520           | 15, 041        |
| **563    | 12, 958        | *571     | 18, 816        | *542     | 9, 292         | *574            | 15, 331        |
| *524     | 13, 008        | **555    | 19, 745        | *609     | 9, 292         | *528            | 15, 401        |
| **566    | 13, 203        | 566      | 19, 746        | *585     | 9, 292         | *570            | 15, 475        |
| *578     | 13, 241        | *527     | 19, 977        | *619     | 9, 292         | *535            | 15, 486        |
| *582     | 13, 241        | 538      | 19, 977        | 547      | 9, 292         | *518            | 15, 581        |
| **547    | 13, 473        | *562     | 19, 978        | *546     | 9, 872         | 523             | 15, 598        |
| *597     | 13, 473        | **561    | 20, 442        | *554     | 9, 872         | **547           | 15, 796        |
| *615     | 13, 473        |          |                | *505     | 9, 872         | *599            | 15, 796        |
|          |                |          |                | 520      | 9, 872         |                 |                |

<sup>a</sup>The number of stars indicates how many times the line has ranked among the lowest 20. Lines not starred in columns 3 and 4 appear and are starred elsewhere in the table. Three appear three times, 8 appear twice, and 38 appear only once.

It will be noted from Tables XIX and XX that in either case the greater number of these lines have appeared only once in either of these groups. Line 561 appears in the low-yielding groups of 1916 and 1917 but is the highest-yielding line of 1918. It also appears among the 40 lines selected in 1918 as having the best vines. While the performance record may not so indicate, it is undoubtedly one of the good lines of this variety. Aside from this one line, none of those that have ranked twice among the lowest 20 according to the 3-year average appear among those selected in 1918 as having good vine characteristics. We may safely say that the performance record is more reliable as a means of eliminating the lowest-yielding lines than in pointing out the higher-yielding ones. The following 1918 field notes show that in this as well as in the other varieties yield records will not eliminate lines with degenerate tendencies.

| LINE NO. | REMARKS.   |
|----------|--|
| 552.     | A good dark green type.                                |
| 551.     | A good dark green type.                                |
| 608.     | A good dark green type.                                |
| 609.     | A good dark green type.                                |
| 604.     | A good dark green type.                                |
| 580.     | A good dark green type.                                |
| 525.     | Third unit lacking in color; others good.              |
| 584.     | A good dark green type.                                |
| 589.     | First unit not a good type.                            |
| 618.     | A good dark green type.                                |
| 596.     | A good dark green type.                                |
| 612.     | First unit lacking in color.                           |
| 605.     | A good dark green type.                                |
| 614.     | Third, fourth, and fifth units not good type.          |
| 593.     | Color not good although the line is quite vigorous.    |
| 603.     | A good dark green type.                                |
| 568.     | Lacking in color but fairly vigorous.                  |
| 595.     | A good dark green type.                                |
| 549.     | A good dark green type.                                |
| 531.     | Last unit showing a tendency to burn.                  |
| 577.     | A good dark green type.                                |
| 607.     | A good dark green type.                                |
| 548.     | A good dark green type.                                |
| 585.     | Last unit light-colored and burning; others very good. |

Of these 26 lines which have appeared at least twice among the highest-ranking 20 or would be ranked among the highest 20 on their 3-year average production by weight, 17 have good records as to vine characteristics and 9 contain some vines of a degenerate type. It will be remembered that loss of vitality is indicated in this variety by a loss of color and a tendency for the leaves to burn about the edges in typical degenerates.

In Table XXI will be found data upon the 3-year average numerical tuber production of Early Six Weeks. The maximum variation found is 1.78 tubers per hill. The annual average tuber production shows even greater variation. These 100 tuber lines averaged 2.12 tubers per hill in 1916, 4.04 in 1917, and 2.63 in 1918. The 20 highest and 20 lowest yielding lines when ranked upon tuber production in numbers have been grouped in Tables XXII and XXIII. The first 8 lines starred in Table XXIII are typical degenerates with bad yield records by weight. There are, however, 5 lines in Table XXIII which also appear in Table XXIV among the 40 with good vine characteristics in 1918. Going back to Table XVIII, it will be noticed that these 5 lines have very good records when judged on tuber production by weight. It is true that none of them are high yielders, but they fall very close to the average of the 100 lines. Fourteen of the lines in Table XXII appear in Table XXIV, or among those selected in 1918 as having good vine characteristics.

TABLE XXI.—Three-year average numerical production of marketable tubers per hill from 100 Early Six Weeks tuber lines

| Line No. | Yield. | Line No. | Yield. | Line No. | Yield. | Line No. | Yield. |
|----------|--------|----------|--------|----------|--------|----------|--------|
| 517..... | 3.02   | 543..... | 2.77   | 571..... | 3.18   | 597..... | 3.25   |
| 518..... | 2.41   | 545..... | 2.41   | 572..... | 3.20   | 599..... | 3.22   |
| 519..... | 2.84   | 546..... | 3.29   | 573..... | 2.70   | 600..... | 3.15   |
| 520..... | 2.09   | 547..... | 3.25   | 574..... | 3.15   | 601..... | 3.29   |
| 522..... | 3.00   | 548..... | 3.05   | 575..... | 3.27   | 602..... | 3.27   |
| 523..... | 3.07   | 549..... | 3.03   | 576..... | 2.84   | 603..... | 3.47   |
| 524..... | 2.86   | 550..... | 2.92   | 577..... | 3.95   | 604..... | 3.85   |
| 525..... | 3.23   | 551..... | 3.50   | 578..... | 3.00   | 605..... | 3.25   |
| 526..... | 2.90   | 552..... | 3.11   | 579..... | 2.86   | 606..... | 3.32   |
| 527..... | 2.79   | 553..... | 3.17   | 580..... | 3.23   | 607..... | 3.50   |
| 528..... | 3.16   | 554..... | 3.11   | 581..... | 3.40   | 608..... | 3.95   |
| 529..... | 3.45   | 555..... | 3.18   | 582..... | 3.48   | 609..... | 3.90   |
| 530..... | 3.13   | 556..... | 3.23   | 583..... | 3.20   | 610..... | 3.11   |
| 531..... | 3.27   | 558..... | 3.33   | 584..... | 3.64   | 611..... | 2.97   |
| 532..... | 3.47   | 559..... | 2.93   | 585..... | 3.50   | 612..... | 3.43   |
| 533..... | 3.09   | 560..... | 2.86   | 586..... | 3.30   | 613..... | 3.23   |
| 534..... | 2.72   | 561..... | 3.36   | 588..... | 3.00   | 614..... | 3.40   |
| 535..... | 3.00   | 562..... | 3.39   | 589..... | 3.78   | 615..... | 2.77   |
| 536..... | 2.79   | 563..... | 2.05   | 590..... | 3.34   | 616..... | 3.11   |
| 537..... | 3.43   | 564..... | 3.40   | 591..... | 3.40   | 617..... | 3.16   |
| 538..... | 2.81   | 565..... | 3.00   | 592..... | 3.29   | 618..... | 3.52   |
| 539..... | 3.15   | 566..... | 2.74   | 593..... | 3.39   | 619..... | 3.00   |
| 540..... | 3.12   | 568..... | 3.80   | 594..... | 2.93   | 620..... | 3.02   |
| 541..... | 3.47   | 569..... | 3.06   | 595..... | 3.81   | 621..... | 2.17   |
| 542..... | 3.02   | 570..... | 2.79   | 596..... | 3.60   | 622..... | 3.28   |

TABLE XXII.—Twenty highest of 100 Early Six Weeks tuber lines when ranked on 3-year average numerical production of marketable tubers per hill<sup>a</sup>

| Line No.  | Yield. | Line No.  | Yield. | Line No.  | Yield. | Line No.  | Yield. |
|-----------|--------|-----------|--------|-----------|--------|-----------|--------|
| *608..... | 3.95   | *568..... | 3.80   | *549..... | 3.63   | *607..... | 3.50   |
| *577..... | 3.95   | *589..... | 3.78   | *596..... | 3.60   | 582.....  | 3.48   |
| 609.....  | 3.90   | *533..... | 3.69   | *618..... | 3.52   | 532.....  | 3.47   |
| *604..... | 3.85   | *548..... | 3.65   | *551..... | 3.50   | 541.....  | 3.47   |
| *595..... | 3.81   | *584..... | 3.63   | *585..... | 3.50   | *603..... | 3.47   |

<sup>a</sup> The lines starred also appear among the 20 highest-yielding when ranked on 3-year average production by weight. Thirteen of these lines (in bold-face type) have uniformly good vine characteristics; the other 7 lines contained plants suggesting degeneration. Average of group, 3.65 tubers per hill.

TABLE XXIII.—Twenty lowest of 100 Early Six Weeks tuber lines when ranked on 3-year average numerical production of marketable tubers per hill<sup>a</sup>

| Line No.  | Yield. | Line No.  | Yield. | Line No.  | Yield. | Line No.  | Yield. |
|-----------|--------|-----------|--------|-----------|--------|-----------|--------|
| *621..... | 2.17   | *373..... | 2.70   | *527..... | 2.79   | *576..... | 2.84   |
| *518..... | 2.41   | *534..... | 2.72   | 536.....  | 2.79   | 524.....  | 2.86   |
| *545..... | 2.41   | *566..... | 2.74   | *570..... | 2.79   | 560.....  | 2.86   |
| *563..... | 2.65   | 543.....  | 2.77   | *538..... | 2.81   | 578.....  | 2.86   |
| *520..... | 2.69   | 615.....  | 2.77   | 519.....  | 2.84   | 526.....  | 2.90   |

<sup>a</sup> The lines starred also appear among the 20 lowest yielding when ranked on 3-year average production by weight. The lines printed in bold-faced type appear among the 40 chosen in 1918 as having good vine characteristics. Average of group, 2.71 tubers per hill.

TABLE XXIV.—Yields in 1918 of 40 Early Six Weeks tuber lines chosen upon 1918 vine characteristics alone as the best of the 100 lines of this variety<sup>a</sup>

| Line No.  | Yield.         | Line No.  | Yield.         | Line No.  | Yield.         | Line No.  | Yield.         |
|-----------|----------------|-----------|----------------|-----------|----------------|-----------|----------------|
|           | <i>Pounds.</i> |           | <i>Pounds.</i> |           | <i>Pounds.</i> |           | <i>Pounds.</i> |
| 517.....  | 19, 513        | *549..... | 24, 391        | 569.....  | 20, 210        | 601.....  | 19, 048        |
| *519..... | 17, 654        | *551..... | 25, 553        | 571.....  | 21, 139        | *604..... | 21, 516        |
| *522..... | 19, 804        | *552..... | 25, 553        | *575..... | 19, 977        | *605..... | 20, 442        |
| *526..... | 20, 293        | *554..... | 20, 907        | *577..... | 19, 513        | *607..... | 18, 584        |
| *529..... | 18, 351        | *558..... | 20, 049        | *580..... | 21, 271        | *608..... | 22, 005        |
| *532..... | 18, 584        | *560..... | 20, 538        | *584..... | 19, 071        | *609..... | 21, 516        |
| 536.....  | 18, 119        | *561..... | 29, 502        | *591..... | 20, 907        | 610.....  | 16, 261        |
| 540.....  | 19, 977        | *562..... | 27, 873        | *594..... | 17, 654        | *618..... | 19, 048        |
| 543.....  | 22, 300        | 564.....  | 19, 048        | *595..... | 21, 027        | 620.....  | 18, 119        |
| *548..... | 25, 320        | 565.....  | 20, 907        | 600.....  | 17, 654        | *622..... | 19, 358        |

<sup>a</sup> The 26 lines starred also appear among the 40 highest-yielding when ranked on the 3-year average tuber production by weight. The others have very good records for the 3-year period. Average of group, 20,713 pounds per acre.

The vine growth of the other 6 lines is reported in the following 1918 field notes:

LINE NO.

REMARKS.

568. A little lacking in color but fairly vigorous.  
 589. A very good type with possible exception of first unit.  
 533. First unit light colored and burning; other plants green and vigorous.  
 596. A very good green type; first two hills lacking in vigor, but this is possibly due to soil.  
 585. Type fair with exception of last unit, which shows some burning.  
 582. A light-colored, burning type.  
 541. A good green type with exception of first unit, which is distinctly lighter and burning.

In Table XXIV data are assembled to show the relation between good vine characteristics and tuber production in Early Six Weeks. The 40 lines with best vine characteristics gave an average yield of 20,713 pounds per acre in 1918, while the 41 heaviest-yielding lines of 1918 grouped in Table XXV averaged 21,350 pounds. The 1918 average of the 100 Early Six Weeks lines was 17,344 pounds of marketable tubers per acre. In this variety vine growth is almost as reliable as yield records in pointing out high-yielding lines. The 3-year average yield of the 40 lines in Table XXIV was 19,515 pounds per acre, while the 40 lines ranking highest on 3-year average tuber production by weight yielded during the same period an average of 20,455 pounds. Will it pay to keep yield records when 40 per cent of the heaviest-yielding lines chosen with the aid of 3 years' data do not produce 1,000 pounds per acre more than do 40 per cent selected in less than 2 hours upon vine characteristics alone?

TABLE XXV.—*Forty-one highest-yielding of 100 Early Six Weeks lines in 1918*<sup>a</sup>

| Line No. | Yield.         | Line No. | Yield.         | Line No. | Yield.         | Line No. | Yield.         |
|----------|----------------|----------|----------------|----------|----------------|----------|----------------|
|          | <i>Pounds.</i> |          | <i>Pounds.</i> |          | <i>Pounds.</i> |          | <i>Pounds.</i> |
| 561..... | 29, 502        | 604..... | 21, 516        | 560..... | 20, 538        | 550..... | 19, 745        |
| 562..... | 27, 873        | 609..... | 21, 516        | 605..... | 20, 442        | 517..... | 19, 513        |
| 551..... | 25, 553        | 525..... | 21, 271        | 526..... | 20, 293        | 577..... | 19, 513        |
| 552..... | 25, 553        | 533..... | 21, 271        | 569..... | 20, 210        | 622..... | 19, 358        |
| 548..... | 25, 320        | 580..... | 21, 271        | 586..... | 20, 210        | 584..... | 19, 071        |
| 549..... | 24, 391        | 571..... | 21, 139        | 589..... | 20, 132        | 539..... | 19, 048        |
| 546..... | 22, 765        | 595..... | 21, 027        | 558..... | 20, 049        | 564..... | 19, 048        |
| 531..... | 22, 713        | 554..... | 20, 907        | 540..... | 19, 977        | 585..... | 19, 048        |
| 543..... | 22, 300        | 565..... | 20, 907        | 575..... | 19, 977        | 601..... | 19, 048        |
| 608..... | 22, 005        | 591..... | 20, 907        | 522..... | 19, 804        | 618..... | 19, 048        |
| 541..... | 21, 603        |          |                |          |                |          |                |

<sup>a</sup>The 31 lines printed in bold-face type also appear in Table XXIV. This leaves 10 of these high-yielding lines with poor vine characteristics. Average of group, 21,350 pounds per acre.

### CONCLUSIONS

The data presented, so far as the author is able to judge, do not furnish very strong evidence of the presence of high-yielding lines within the common population of the varieties studied. The real test of the existence of such lines is ability to maintain a high-yielding progeny by indiscriminate mass selection.

Short performance records are fairly reliable in eliminating lines with low-yielding tendencies, but they are not so reliable as a basis upon which to select plus variations if such really exist.

If degenerate tendencies exist within certain clonal lines and not in others, short performance records are of little value in eliminating the undesirable lines.

Degenerate individuals appear with such persistent regularity within line selections as to become a real stumblingblock. If there are no exceptions to this rule, before a hill or tuber line can be increased to a point where it is of real value in commercial potato production it is almost certain to contain degenerate types which soon reduce its yielding power to that of the common population of the variety.

The data presented will not justify an indorsement of the plan of clonal line selection as a practical method of potato-seed improvement. This does not mean that the hill-selection method of choosing potato seed is without merit. Generally speaking, high-yielding hills selected upon production by weight will produce the following season a high-yielding progeny. It does mean, however, that to be effective hill selection becomes an annual task. I believe there is a more practical method of potato-seed improvement.

Since certain vine characteristics are so closely correlated with yields, selection based on vine development alone promises to be more reliable than selection based on tuber production either by weight or number, and much more practical.

At present, selection based chiefly on vine characteristics seems to be the only hope in dealing with degeneration. The success of such selection is measured by one's ability to identify intermediate types as well as typical curlydwarf degenerates.

A special seed plot in which the seed pieces from each tuber are planted in consecutive hills promises to afford the best solution of the problems of degeneration and the maintenance of high-yielding variety populations.

Seed for such a plot may be selected in one of two ways. Especially vigorous hills may be marked in the field during the growing season, and the crop from these may be dug and used for planting the special seed plot of the following season, or seed may be selected in the field at digging time or from the bin. The first method will insure the greater return from the first seed plot, especially if the field from which the seed is selected contains a large percentage of degenerate plants. In selecting seed in the field after the digger or from the bin, one may to a certain extent avoid degenerate types by observing certain tuber characteristics. (1) Choose seed tubers rather above the average size for the variety. (2) Select those that are long rather than short for the variety and with both ends full and rounded, not pointed. (3) Choose those that are oval rather than round in cross section, or, in other words, flattened tubers. (4) Pick tubers with conspicuous and moderately deep eyes.

The seed plot can best be planted by hand. The rows should be spaced the usual distance apart and the hills placed 12 or 15 inches apart in the row. On good, fertile, irrigated land, where the recommendations in regard to thinning are to be carried out, the hills should be spaced at 12 or even 10 inches apart. The tubers should be taken to the field whole and then cut as planted. The seed pieces may be cut rather small if seed is not abundant. Single-eye seed pieces weighing from  $\frac{1}{2}$  to 1 ounce will give just as good results as larger pieces. These are conveniently planted with a hoe, and if small should not be covered over 3 inches deep. Each tuber is cut by itself, and the pieces are dropped in consecutive hills. Not only is it important to have the hills from each tuber in a group, but it is desirable to have these groups marked off one from the other. This may be accomplished in several ways. A good way is to drop a hill of corn between the groups. The important point, however, is to have the hills from each tuber in a group. This is the only way if intermediate types are to be eliminated from the seed plot by roguing. Mixtures are also easily detected where the hills are in tuber groups.

The seed plot should be thinned by removing all but one stalk from each hill. Thinning should be done as soon as the vines are large enough to pull, usually from five to six weeks after planting. Proper comparisons can best be made between hills with a uniform number of stems, and this is the real object of thinning. But single-stemmed hills also produce tubers of a more uniform size, and this is desirable, especially if the seed stock is to be offered for sale. Regardless of the merits of the case, the public commonly thinks of good potato seed as uniform-sized stock.



Roguing the seed plot is the most important step in the production of good seed. This consists in going over the field several times during the season and removing undesirable hills. In the first place, there may be variety mixtures in the seed plot. These mixtures are detected chiefly by variations in foliage, color of blossoms, amount of blossoms produced, and dates of ripening. There will also be some weak and degenerate types and diseased hills to be removed. The plot should first be gone over about blooming time, as variety mixtures are then very likely to be most conspicuous. A group of hills may show blossoms that are off type in color, or a certain group of hills may bloom more or less than the other plants in the plot. These hills should be dug and the tubers removed from the field. A little later the plot should be gone over again to catch hills lacking in vigor or infected with disease. In early varieties, this examination should be made just about the time the most vigorous vines show signs of maturing. At this time some vines will be found fully mature. This premature ripening is probably brought on by disease, and the hills should be removed. Such hills most frequently appear at random, but occasionally all the hills from a seed tuber may be diseased. In looking for weak plants, the hills from each tuber should be studied as a group. Weak hills will show a more crinkled foliage and usually less vigorous vines. It is well to remember that the intermediate types are the real trouble makers. They are usually as vigorous as normal hills, but show a slight crinkling of the foliage and are very often of a lighter shade of green.<sup>1</sup> In looking for these weak groups it is best not to work too near the row being examined. First look each row over at close quarters and then from two or three rows distant. In roguing out late varieties, the work must always be done before the vines are touched with frost. Remember that in roguing the tubers as well as the vines must be dug and removed from the seed plot.

If the seed plot has been carefully rogued, the entire crop may be saved for seed. Occasionally a group of hills may produce tubers of poor form, and these may be discarded. The small seed from such a seed plot is just as satisfactory as the large, and in the great majority of cases variations in form are nothing more than fluctuations and as such are not transmitted to the following crop.

In many instances the improvement secured by growing a variety in a special seed plot of this kind for one season may be apparent for two or three years after returning to the practice of selecting seed at random from the field at digging time or from the bin; but permanent improvement can be maintained only by continuing the special seed plot year after year. With most varieties it is allowable, if the roguing is carefully done, to increase the seed secured from the seed plot by planting it in a certain part of the commercial field and then saving

<sup>1</sup>WHIPPLE, O. B. DEGENERATION IN POTATOES. *Mont. Agr. Exp. Sta. Bul.* 130, 29 p., 16 fig. 1919.

from this part of the field seed for the entire acreage the following season. But if one is not absolutely sure he can pick out the intermediate types in roguing, this practice may prove disappointing. Once the special seed plot is established, it may well be continued from year to year, the seed for the special seed plot of each year being selected from the seed plot of the year before. It is even advisable to go into the special seed plot and mark especially promising groups of hills to be dug to furnish seed for the seed plot of the following year.



# OCCURRENCE OF THE FIXED INTERMEDIATE, *HORDEUM INTERMEDIUM HAXTONI*, IN CROSSES BETWEEN *H. VULGARE PALLIDUM* AND *H. DISTICHON PALMELLA*<sup>1</sup>

By HARRY V. HARLAN, *Agronomist, Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture*, and H. K. HAYES, *Head of Section of Plant Breeding, Division of Agronomy and Farm Management, Minnesota Agricultural Experiment Station*

## INTRODUCTION

The cultivated barleys belong to the genus *Hordeum* and are characterized by the presence of three single-flowered spikelets at each node of the rachis. The floret of the central spikelet develops a normal kernel in all forms of barley. The lateral florets, on the other hand, may develop normal or undersized kernels or may be sterile or even abortive. In classifying the varieties, Harlan (2)<sup>2</sup> recognized four species, basing them on the degree of fertility in the lateral florets. Varieties of three of these species are concerned in the data presented herein. In all varieties mentioned, the central florets are long-awned. The 6-rowed parents in all hybrids belonged to the botanical variety *H. vulgare pallidum*, and include Manchuria, S. P. I. No. 20375, Sex-radigt, Odessa, Reid Triumph, Surprise, and a hybrid 6-rowed  $\times$  2-rowed barley. The lateral as well as the central florets of these varieties are long-awned and produce well-developed kernels.

The 2-rowed parents all belong to the variety *H. distichon palmella*. The central florets are long-awned, while the lateral ones are awnless with rounded tips and are sterile. Of the varieties mentioned in the text, Svanhals, Garton, and Primus belong to this group. The intermediates are products of hybridization, and the selections are unnamed. All, however, belong to the botanical variety *H. intermedium haxtoni*. In these the central florets are long-awned and produce normal kernels, while the lateral florets are awnless, as in the 2-rowed barleys, but fertile, producing undersized but viable kernels. The percentage of fertility in these spikelets is not so high as in the 6-rowed, but neither are they infertile, as are the 2-rowed. This form, obviously intermediate in character between the 6-rowed and 2-rowed barleys, has proved to be constant and is as distinct in its genetic behavior as either the 6-rowed or the 2-rowed forms.

The history of the intermediate barleys is very interesting, but not always clear. The first recorded observation found is that of John Haxton (3) in Scotland. In Morton's *Cyclopedia of Agriculture* of 1851 he mentions having observed such a plant in a field of "Bere." At the time

<sup>1</sup> This paper is based upon experiments conducted cooperatively by the Office of Cereal Investigations, Bureau of Plant Industry, United States Department of Agriculture, and the Minnesota Agricultural Experiment Station.

<sup>2</sup> Reference is made by number (*italic*) to "Literature cited," pp. 590-591.

of this description he obviously had the heterozygous intermediate or a mixture of this and the homozygous intermediate, since he obtained all types from the seeding. Later, the homozygous form seems to have been isolated. In 1883, Drechsler of Göttingen sent Rimpau an intermediate which he had found in a field of *H. distichon palmella zeocrion* and which apparently bred true from the time of its discovery. Both Rimpau (6, 7) and Körnicke (4) observed the intermediate. According to Körnicke's statement of 1885, he found the intermediate as an accidental hybrid in a field of 2-rowed winter barley. At first the selection was heterozygous, but, according to the statement of his son (5), in 1908, it later became constant. Both Rimpau and Körnicke made mass selections which evidently included heterozygous forms, at least at first. It is probable that homozygous types were eventually obtained.

These four cases of probable isolation of the fixed intermediate all occurred before 1900 and, therefore, before the importance of plant selections in hybrids was generally recognized. It is worthy of note that all four were instances where accidental hybrids were observed, rather than the products of any of the numerous crosses made by those investigators.

The history since 1900 is more surprising than that previous to 1900. The modern methods of breeding lead to the direct and ready isolation of this type, yet, so far as the authors know, it has not been reported. Since 1900, indeed, two plant breeders who have worked extensively with barley have assumed that a fixed intermediate does not occur in crosses between 6-rowed and 2-rowed barleys. Von Tschernak (8) says as late as 1914 that the intermediate form with fertile lateral florets is heterozygous and, therefore, is never constant. Biffin (1), while not so sweeping in his statement, must have held a similar view. In 1907, he reported nine crosses in which a homozygous intermediate might occur. From the  $F_2$  progeny of one of these he selected a considerable number of intermediates of two types and planted them. All proved to be heterozygous. He did not test the progeny of the other crosses but assumed that they would behave in the same way. In the discussion he then states:

The heterozygote, therefore, of forms with hermaphrodite staminate lateral florets is potentially hermaphrodite and of the type known to systematists as *H. intermedium*.

In 1907 J. H. Wilson (9) reported an  $F_2$  generation of Standwell  $\times$  Bere, in which he made the following observation:

Examples occurred in which the grains of all six rows were fully developed, but the lateral ones were without awns.

In this case Mr. Wilson probably noticed the homozygous type. It is interesting that he should have used as the 6-rowed parent the variety of barley in which Haxton found the first recorded intermediate.

The observations of the senior author in these studies extend over the past 10 years. In the summer of 1909 he made a large number of hybrids on the grounds of the Minnesota Agricultural Experiment Station. A con-

siderable number of these were between 2-rowed and 6-rowed parents. In 1910 the  $F_1$  generation was grown, and in 1911 the  $F_2$  generation. In the  $F_1$  generation of 1910 the heterozygous intermediate was very vigorous, and a considerable number of selections were grown in 1911 from the small lateral kernels to see if they would produce vigorous plants. In the  $F_2$  generation it was apparent that there were intermediates present which differed from those of 1910, and 56 selections of different types of intermediates were grown in 1912. These came from 12 different crosses and included the progeny of combinations of 10 different 2-rowed and 7 different 6-rowed parents. A number of these proved to be homozygous, and others were isolated from the  $F_2$  generation by further selection. Unfortunately, the records of 1912 are incomplete, and the total number of homozygotes obtained can not be determined. It is also impossible to establish the complete list of crosses from which fixed intermediates were obtained. Beyond all question, from one to five fixed intermediates were obtained from each of five different crosses. These crosses involve three different 2-rowed and five different 6-rowed parents. In these cases original material or complete records of the progeny are still at hand. The crosses were as follows: S. P. I. No. 20375  $\times$  Svanhals, Surprise  $\times$  Primus, Primus  $\times$  (2-rowed  $\times$  6-rowed), Garton 2-rowed  $\times$  Sex-radigt, and Manchuria  $\times$  Svanhals. There is a definite statement in the field records that a selection of *zeocriton*  $\times$  Manchuria and another of Chevalier  $\times$  South African were fixed intermediates, but there are neither specimens nor progeny records to confirm these statements.

It will be seen that in the five crosses where the evidence is complete the 2-rowed parents were dense-spiked. Aside from the fact that those which have been preserved came from such crosses, there is no evidence in the data now at hand that indicates inability to secure intermediates from crosses in which both parents are lax-spiked. The common varieties of lax 2-rowed barleys have less vigorous lateral florets than the common varieties of dense 2-rowed barleys. It is possible that the progeny of crosses where the lax forms were used would be lower in fertility and the intermediates correspondingly less conspicuous. Hence, they would be less desirable and less likely to be retained as specimens.

In 1915, after the junior author became connected with the Minnesota Agricultural Experiment Station, it was decided to repeat one of the crosses from which fixed intermediates had been secured, in order to determine the inheritance and, if possible, to discover an explanation of the occurrence of this form. By making crosses and growing an occasional generation in the greenhouse in Washington in the winter and sowing the seed in Minnesota in the spring several generations have been studied since that date. The cross chosen for this purpose was Manchuria  $\times$  Svanhals. The  $F_2$  and  $F_3$  generations are reported in detail. Other crosses were studied in which no intermediates were produced; but since the data are negative, they have not been included,

although reference is made in the discussion to them and their significance.

OCURRENCE OF *H. INTERMEDIUM* AND OTHER SEGREGATES IN THE PROGENY OF A CROSS OF MANCHURIA AND SVANHALS BARLEYS

The Manchuria parent in this cross is a selection of the common 6-rowed barley of the northern Mississippi Valley. The side florets are fertile and long-awned. The Svanhals parent is a well-known 2-rowed variety with long-awned, fertile, central florets and awnless, rounded, sterile lateral ones. The Manchuria is illustrated in Plate 103, C, and the Svanhals in Plate 104, A. This cross was made in the Washington greenhouse in the spring of 1917, and the  $F_1$  generation was grown the same season at the University of Minnesota. In the fall of 1917, 100 of these  $F_1$  seeds were sown in pots in the Washington greenhouse. Of these, only 87 matured as  $F_2$  plants in the spring of 1918. As soon as the grain was sufficiently mature to harvest seed was again sent to Minnesota, where the  $F_2$  generation was grown.

PHENOTYPIC CLASSES IN THE PROGENY

The data on the  $F_2$  generation are reported in Table I, which needs considerable explanation. In the first place, the material itself is not simple. It is far from easy for a reader unfamiliar with barley to visualize six classes of segregates. Added to this difficulty is the fact that the  $F_2$  classifications are of varying accuracy and are phenotypic in character. The phenotypic classes of the table give a misleading impression by over-emphasizing the importance of the amount of fertility present. There are other characters than fertility which have much significance in the genetic groups. Fertility, however, is a definite, tangible, measurable condition, and the phenotypic classes founded on it are usable. In some instances the phenotypic classes of the  $F_2$  generation coincide with the genetic classes, while in others a phenotypic class contains more than one genetic class. There is a certain amount of unavoidable confusion in describing both phenotypic and genetic classes at the same time. For this reason, until the genetic classes are established the plants exhibiting similar phenotypic classes in their progeny are placed together and referred to as genetic groups. It must be remembered in studying the table that the main object of the  $F_2$  classification was to determine the genetic classes of the  $F_2$  generation. It is well also to recall at this time that all classifications in this paper are based on the nature of the lateral florets, and to avoid endless repetition the modifying adjective is frequently omitted. In such cases the terms sterile, awn-pointed, high fertility, etc., refer to the lateral florets only.

Table I represents the data as taken. The first two columns of the table contain the identification numbers and the description of the  $F_2$  plants. In the remaining columns the  $F_3$  progeny of these plants are classified. These progeny fall into two major divisions, in one of which

all the kernels are of normal size, while in the other they are subnormal or absent. This second division is separated into plants which have lateral florets with awned or awn-pointed lemmas and plants in which the lemmas of the lateral florets are awnless and more or less rounded. Further subdivisions were based on the percentage of fertility of the lateral florets. The nature of the six resulting classes is illustrated in Plates 103 and 104. It is readily apparent in Plate 103 that the three classes with awned or awn-pointed lemmas on the lateral florets are easily separated. It is just as apparent in Plate 104 that the accident of season or nutrition can easily affect the classification of the segregates with rounded lemmas. Errors of classification in this case happen to be unimportant, for, as previously stated, the object of the  $F_2$  classification is only to determine the nature of the  $F_2$  parent. This is made evident in all cases by the classification used. To make this clear, one of the findings must be anticipated. Of the six classes in which the  $F_2$  plants are divided, three are of special importance in the interpretation. These are the fully fertile long-awned, the high-fertility awnless, and the no-fertility awnless classes. These represent the 6-rowed, the *intermedium*, and the 2-rowed barleys. In all cases the classification is sufficiently accurate to determine which of these classes are to be found in the progeny of each  $F_2$  plant.

TABLE I.—Classification of 87  $F_2$  plants and their  $F_3$  progeny in a cross between *Manchuria* and *Svanhals* barleys according to the nature of their lateral florets

GROUP 1, PLANTS WHICH GAVE ONLY 6-ROWED PROGENY

| F <sub>2</sub> parent No. | F <sub>2</sub> parent type. | Number of individuals in F <sub>3</sub> progeny, by classes.     |                                      |                                |  |                                 |                           | Total. |
|---------------------------|-----------------------------|--|--------------------------------------|--------------------------------|--|---------------------------------|---------------------------|--------|
|                           |                             | Kernels normal size, lemmas long-awned, fully fertile (6-rowed). | Kernels subnormal in size or absent. |                                |  |                                 |                           |        |
|                           |                             |  | Lemmas awned or awn-pointed.         |                                | Lemmas awnless.                                  |                                 |                           |        |
|                           |                             |  | High fertility (80-100 per cent).    | Low fertility (0-75 per cent). | Fertility 5-100 per cent ( <i>intermedium</i> ). | Fertility less than 5 per cent. | Fertility none (2-rowed). |        |
| 2                         | 6-rowed                     | 20   |                                      |                                |  |                                 |                           | 20     |
| 7                         | do.                         | 24   |                                      |                                |  |                                 |                           | 24     |
| 11                        | do.                         | 20   |                                      |                                |  |                                 |                           | 20     |
| 13                        | do.                         | 21   |                                      |                                |  |                                 |                           | 21     |
| 23                        | do.                         | 19   |                                      |                                |  |                                 |                           | 19     |
| 33                        | do.                         | 24   |                                      |                                |  |                                 |                           | 24     |
| 38                        | do.                         | 20   |                                      |                                |  |                                 |                           | 20     |
| 41                        | do.                         | 45   |                                      |                                |  |                                 |                           | 45     |
| 44                        | do.                         | 23   |                                      |                                |  |                                 |                           | 23     |
| 45                        | do.                         | 19   |                                      |                                |  |                                 |                           | 19     |
| 49                        | do.                         | 21   |                                      |                                |  |                                 |                           | 21     |
| 50                        | do.                         | 20   |                                      |                                |  |                                 |                           | 20     |
| 60                        | do.                         | 44   |                                      |                                |  |                                 |                           | 44     |
| 70                        | do.                         | 23   |                                      |                                |  |                                 |                           | 23     |
| 72                        | do.                         | 22   |                                      |                                |  |                                 |                           | 22     |
| 75                        | do.                         | 18   |                                      |                                |  |                                 |                           | 18     |



TABLE I.—Classification of 37  $F_2$  plants and their  $F_3$  progeny in a cross between *Manchuria* and *Svanhals* barleys according to the nature of their lateral florets—Con.

## GROUP 1, PLANTS WHICH GIVE ONLY 6-ROWED PROGENY—continued.

| F <sub>2</sub><br>parent<br>No. | F <sub>2</sub> parent type. | Number of individuals in F <sub>2</sub> progeny, by classes.                                  |   |  |   |   |                                       | Total. |
|---------------------------------|-----------------------------|---|---|--|---|---|---------------------------------------|--------|
|                                 |                             | Kernels<br>normal<br>size,<br>lemmas<br>long-<br>awned,<br>fully<br>fertile<br>(6-<br>rowed). | Kernels subnormal in size or absent.                |  |   |   |                                       |        |
|                                 |                             |   | Lemmas awned<br>or awn-pointed.                     |  | Lemmas awnless.   |   |                                       |        |
|                                 |                             |   | High<br>fertili-<br>ty<br>(80-100<br>per<br>cent.). | Low<br>fertili-<br>ty<br>(0-79<br>per<br>cent.). | Fertili-<br>ty<br>5-100<br>per cent<br>(inter-<br>me-<br>dium). | Fertili-<br>ty less<br>than<br>5 per<br>cent. | Fertili-<br>ty<br>none (3-<br>rowed). |        |
| 79                              | do                          | 20  |   |  |   |   |                                       | 20     |
| 82                              | do                          | 45  |   |  |   |   |                                       | 45     |
| 88                              | do                          | 34  |   |  |   |   |                                       | 34     |
| 94                              | do                          | 21  |   |  |   |   |                                       | 21     |
| 97                              | do                          | 19  |   |  |   |   |                                       | 19     |
| 100                             | do                          | 15  |   |  |   |   |                                       | 15     |

## GROUP 2, PLANTS WHICH GAVE 6-ROWED AND INTERMEDIUM BUT NO 2-ROWED SEGREGATES

|    |                             |    |    |   |    |   |  |    |
|----|-----------------------------|----|----|---|----|---|--|----|
| 29 | 80 per cent fertile, awned  | 12 | 23 |   | 12 |   |  | 47 |
| 62 | 25 per cent fertile, awned  | 18 | 20 |   | 6  |   |  | 44 |
| 64 | 90 per cent fertile, awned  | 16 | 20 |   | 10 |   |  | 46 |
| 85 | 33 per cent fertile, awned  | 7  | 15 | 2 | 10 |   |  | 34 |
| 98 | 90 per cent fertile, awned  | 17 | 13 |   | 10 |   |  | 40 |
| 99 | ...do...                    | 7  | 23 | 1 | 5  | 3 |  | 39 |
| 37 | 5 per cent fertile, awnless | 7  | 30 |   | 6  |   |  | 43 |

## GROUP 3, PLANTS WHICH GAVE 6-ROWED, INTERMEDIUM, AND 2-ROWED SEGREGATES

|    |                            |    |    |    |   |   |    |    |
|----|----------------------------|----|----|----|---|---|----|----|
| 12 | 5 per cent fertile, awned  | 15 | 14 | 8  | 0 | 0 | 4  | 41 |
| 17 | 3 per cent fertile, awned  | 11 | 12 | 7  | 0 | 1 | 10 | 41 |
| 19 | None fertile, awned        | 9  | 6  | 4  | 1 | 0 | 3  | 23 |
| 25 | ...do...                   | 15 | 9  | 11 | 2 | 1 | 11 | 49 |
| 26 | ...do...                   | 14 | 16 | 10 | 0 | 1 | 9  | 50 |
| 28 | ...do...                   | 8  | 13 | 12 | 3 | 0 | 8  | 44 |
| 31 | ...do...                   | 10 | 19 | 5  | 3 | 0 | 8  | 45 |
| 32 | ...do...                   | 16 | 7  | 13 | 0 | 0 | 10 | 46 |
| 39 | ...do...                   | 9  | 12 | 13 | 1 | 2 | 11 | 48 |
| 40 | ...do...                   | 12 | 13 | 8  | 1 | 1 | 12 | 47 |
| 46 | ...do...                   | 12 | 16 | 12 | 2 | 0 | 5  | 47 |
| 48 | ...do...                   | 14 | 5  | 14 | 0 | 1 | 5  | 39 |
| 55 | ...do...                   | 10 | 14 | 4  | 3 | 1 | 15 | 47 |
| 56 | 9 per cent fertile, awned  | 10 | 16 | 4  | 7 | 1 | 8  | 46 |
| 58 | None fertile, awned        | 17 | 15 | 3  | 4 | 0 | 5  | 44 |
| 59 | ...do...                   | 12 | 17 | 6  | 1 | 2 | 11 | 49 |
| 69 | ...do...                   | 24 | 6  | 13 | 1 | 2 | 4  | 50 |
| 71 | 13 per cent fertile, awned | 13 | 6  | 3  | 1 | 0 | 3  | 26 |
| 74 | 12 per cent fertile, awned | 10 | 22 | 0  | 0 | 4 | 8  | 44 |
| 76 | None fertile, awned        | 11 | 8  | 15 | 1 | 3 | 7  | 45 |
| 77 | ...do...                   | 9  | 6  | 14 | 1 | 1 | 8  | 39 |
| 78 | ...do...                   | 11 | 1  | 13 | 1 | 0 | 19 | 45 |
| 81 | ...do...                   | 16 | 7  | 16 | 1 | 0 | 7  | 47 |
| 84 | ...do...                   | 15 | 11 | 11 | 1 | 0 | 6  | 44 |
| 96 | ...do...                   | 7  | 10 | 15 | 0 | 0 | 10 | 42 |

TABLE I.—Classification of 87  $F_2$  plants and their  $F_3$  progeny in a cross between *Manchuria* and *Svanhals* barleys according to the nature of their lateral florets—Con.

GROUP 4, PLANTS WHICH GAVE 6-ROWED AND 2-ROWED BUT NO INTERMEDIUM SEGREGATES

| P <sub>1</sub><br>parent<br>No. | F <sub>2</sub> parent type. | Number of individuals in F <sub>3</sub> progeny, by classes.                                 |   |  |   |   |                                       | Total. |
|---------------------------------|-----------------------------|--|---|--|---|---|---------------------------------------|--------|
|                                 |                             | Kernels<br>normal<br>size,<br>lemmas<br>long-<br>awned,<br>fully<br>fertile<br>(6-<br>rowed) | Kernels subnormal in size or absent.            |  |   |   |                                       |        |
|                                 |                             |  | Lemmas awned<br>or awn-pointed.                 |  | Lemmas awnless.   |   |                                       |        |
|                                 |                             |  | High ferti-<br>lity<br>(80-100<br>per<br>cent). | Low ferti-<br>lity<br>(0-79<br>per<br>cent). | Ferti-<br>lity<br>5-100<br>per cent<br>(inter-<br>me-<br>dium). | Ferti-<br>lity less<br>than<br>5 per<br>cent. | Ferti-<br>lity<br>none (2-<br>rowed). |        |
| 9                               | None fertile, awned.....    | 5  |   | 15   |   |   | 4                                     | 24     |
| 34                              | do.....                     | 17   |   | 19   |   |   | 9                                     | 45     |
| 35                              | do.....                     | 6  |   | 14   |   |   | 4                                     | 24     |
| 36                              | do.....                     | 7  |   | 26   |   |   | 11                                    | 44     |
| 47                              | do.....                     | 11   |   | 25   |   |   | 11                                    | 47     |
| 54                              | do.....                     | 12   |   | 25   |   |   | 10                                    | 47     |
| 65                              | do.....                     | 13   |   | 15   |   |   | 19                                    | 47     |
| 68                              | do.....                     | 12   |   | 16   |   |   | 15                                    | 43     |
| 83                              | do.....                     | 7  |   | 21   |   |   | 10                                    | 38     |
| 86                              | do.....                     | 11   |   | 19   |   |   | 13                                    | 43     |

GROUP 5, PLANTS WHICH GAVE ONLY INTERMEDIUM FORMS

|    |                                   |  |  |  |    |    |  |    |
|----|-----------------------------------|--|--|--|----|----|--|----|
| 10 | 10 per cent fertile, awnless..... |  |  |  | 47 |    |  | 47 |
| 16 | None fertile, awnless.....        |  |  |  | 39 | 7  |  | 46 |
| 18 | do.....                           |  |  |  | 44 |    |  | 44 |
| 30 | do.....                           |  |  |  | 41 | 5  |  | 46 |
| 66 | do.....                           |  |  |  | 38 |    |  | 38 |
| 93 | do.....                           |  |  |  | 45 | 15 |  | 60 |
| 95 | 20 per cent fertile, awnless..... |  |  |  | 35 |    |  | 35 |

GROUP 6, PLANTS WHICH GAVE INTERMEDIUM AND 2-ROWED BUT NO 6-ROWED SEGREGATES

|    |                            |  |  |  |    |    |    |    |
|----|----------------------------|--|--|--|----|----|----|----|
| 5  | None fertile, awnless..... |  |  |  | 7  |    | 40 | 47 |
| 6  | do.....                    |  |  |  | 9  |    | 38 | 47 |
| 14 | do.....                    |  |  |  | 10 | 10 | 30 | 50 |
| 15 | do.....                    |  |  |  | 8  | 9  | 24 | 41 |
| 24 | do.....                    |  |  |  | 8  | 1  | 11 | 20 |
| 27 | do.....                    |  |  |  | 6  | 4  | 36 | 46 |
| 42 | do.....                    |  |  |  | 8  | 5  | 30 | 43 |
| 51 | do.....                    |  |  |  | 12 | 3  | 33 | 48 |
| 67 | do.....                    |  |  |  | 11 | 0  | 32 | 43 |
| 80 | do.....                    |  |  |  | 4  | 0  | 42 | 46 |
| 92 | do.....                    |  |  |  | 10 | 4  | 29 | 43 |

GROUP 7, PLANTS WHICH GAVE ONLY 2-ROWED FORMS

|    |                            |  |  |  |  |   |    |    |
|----|----------------------------|--|--|--|--|---|----|----|
| 4  | None fertile, awnless..... |  |  |  |  |   | 46 | 46 |
| 8  | do.....                    |  |  |  |  |   | 46 | 46 |
| 22 | do.....                    |  |  |  |  | 2 | 22 | 24 |
| 73 | do.....                    |  |  |  |  |   | 45 | 45 |
| 80 | do.....                    |  |  |  |  |   |    |    |

## GENETIC GROUPS INDICATED BY THE PROGENY CLASSES

The  $F_2$  plants in Table I are arranged in groups according to the segregation shown in the  $F_3$  generation.

Group 1 consists of plants which gave only 6-rowed progeny in the  $F_3$  generation. Since the parents were 6-rowed, the plants in this group are unquestionably homozygous for this character.

Group 2 consists of plants which gave 6-rowed and *intermedium* but no 2-rowed forms. The  $F_2$  plants evidently correspond to those in the high-fertility column of the  $F_3$  classification. The classification of the high-fertility group is readily made and is highly accurate. Since this group gave 6-rowed, high-fertility, and *intermedium* segregates in approximately a 1 to 2 to 1 ratio, it is safe to assume that the high-fertility plants are heterozygous for 6-rowed  $\times$  *intermedium* which differ by a single factor.

Group 3 gave all three homozygous classes and all heterozygous classes as well. From this it is obvious that this group is comparable to the  $F_2$  generation and is heterozygous for the same factor differences as separate the original 6-rowed  $\times$  2-rowed forms.

Group 4 gave 6-rowed, low-fertility awned, and 2-rowed forms in approximately a 1 to 2 to 1 ratio. Since this low-fertility awned corresponded in appearance to the  $F_2$  parents, it would seem that this group also was heterozygous for 6-rowed  $\times$  2-rowed, which in this instance, however, represents a single factor difference. It gave no *intermedium* forms, nor did it give the high-fertility awned or the low-fertility awnless forms. In other words, the *intermedium* character in both its homozygous and its heterozygous aspects was absent. The fact that this group as well as group 3 is heterozygous for 6-rowed  $\times$  2-rowed, even though more factors are involved in one case than the other, can be reconciled only on the basis that there are two types either of the 6-rowed or of the 2-rowed forms, only one of which carries the possibilities of producing *intermedium* forms.

Group 5 consists entirely of  $F_2$  plants which gave only *intermedium* forms in the  $F_3$  generation. In other words, out of 87  $F_2$  plants there were 7 homozygous for the type which has been noticed so rarely in barley studies and whose very occurrence has been questioned so frequently. That the  $F_2$  plants showed no higher fertility was doubtless due to their being grown in the greenhouse. Those plants of the  $F_3$  generation falling in the low-fertility class merely show the variation which exists. They do not cast any doubt on the genetic character of the  $F_2$  parents, because there were no 2-rowed segregates from any of the seven  $F_2$  plants.

Group 6 gives homozygous intermediates, low-fertility awnless, and no-fertility awnless. The numbers in the classes are not significant in this case, for some sterile spikes of *intermedium* and the larger part of

one heterozygous group are included with the homozygous 2-rowed as phenotypes. The  $F_2$  plants in group 6, however, unquestionably are heterozygous for *intermedium*  $\times$  2-rowed, a single main factor difference separating the *intermedium* and 2-rowed forms.

Group 7 may be considered as composed of plants homozygous for 2-rowed, since with the exception of the two plants noted there was no fertility exhibited in the progeny.

The seven groups just discussed consist of  $F_2$  plants assembled in groups because of their evident similarity of genetic constitution. In other words, these groups are genetic classes in contradistinction to the phenotypic classes of the  $F_2$  generation. In Table II the data on these groups are summarized. The second column of this table gives the genetic constitution of each group. Except for the subdivisions of group 1, this classification was verified in the  $F_3$  generation. In the third column a hypothetical formula is suggested for each group. These formulas are based on a 2-factor difference between the 6-rowed and the 2-rowed forms. The Manchuria 6-rowed parent is supposed to possess both factors, while in the 2-rowed Svanhals parent both supposedly are lacking.

TABLE II.—Summary of  $F_2$  plants of the cross between Manchuria and Svanhals

| Group No. as in Table I. | Genetic constitution as shown by progeny.              | Hypothetical formulas. | Expected Mendelian ratio. | Expected number on basis of 87 plants. | Number obtained in 87 plants. | Description of $F_2$ plants.  |
|--------------------------|--|------------------------|---------------------------|--|-------------------------------|---|
| 1                        | Homozygous for 6-rowed....                             | AABB                   | 1                         |  |                               |   |
| 1                        | Heterozygous for 6-rowed $\times$ regressive 6-rowed.  | AABb                   | 2                         | 22                                     | 22                            | Lateral florets long-awned, fully fertile, kernels normal size.                 |
| 1                        | Homozygous for regressive 6-rowed.                     | Aabb                   | 1                         |  |                               |   |
| 2                        | Heterozygous for 6-rowed $\times$ <i>intermedium</i> . | AaBB                   | 2                         | 11                                     | 7                             | Lateral florets short-awned, highly fertile, kernels small.                     |
| 3                        | Heterozygous for 6-rowed $\times$ 2-rowed.             | AaBb                   | 4                         | 22                                     | 25                            | Lateral florets awn-pointed to short-awned, no fertility to low fertility.      |
| 4                        | Heterozygous for regressive 6-rowed $\times$ 2-rowed.  | Aabb                   | 2                         | 11                                     | 10                            | Lateral florets awn-pointed to short-awned, no fertility.                       |
| 5                        | Homozygous for <i>intermedium</i> .                    | aaBB                   | 1                         | 5                                      | 7                             | Lateral florets enlarged awnless, low fertility to no fertility, kernels small. |
| 6                        | Heterozygous for <i>intermedium</i> $\times$ 2-rowed.  | aaBb                   | 2                         | 11                                     | 11                            | Lateral florets awnless, somewhat enlarged, no fertility.                       |
| 7                        | Homozygous for 2-rowed....                             | aabb                   | 1                         | 5                                      | 5                             | Lateral florets small, awnless, no fertility.                                   |

This hypothesis accounts for the results very well. The 2-rowed segregates of group 7 are homozygous in the absence of both factors. The fixed intermediates or *H. intermedium* forms of group 5 are homozygous for the presence of one factor and for the absence of the other. The heterozygous groups, 2, 3, 4, and 6, are all heterozygous for one or both factors. Groups 2, 4, and 6, which are heterozygous for only one factor, give  $F_3$  progeny of limited distribution. Group 3, which is heterozygous for both factors, gives all classes in the  $F_3$  generation.

Group 1 is the only group offering any complications, and these are of no particular complexity. If the 2-factor hypothesis is tenable, group 1 must include three different classes of 6-rowed forms, two of which are homozygous. If the factor AA is considered epistatic to the factor BB, the three classes of group 1 become phenotypic for 6-rowed and may be considered as a single class. In genetic constitution, however, the homozygous 6-rowed segregate AAbb differs from the parent 6-rowed AABB; and, inasmuch as the BB factor has been lost, the form AAbb is referred to here as a regressive 6-rowed. If this regressive 6-rowed AAbb were crossed on the Svanhals parent aabb, there would be no possibility of securing the homozygous intermediate aaBB. Heterozygous types corresponding to such a cross probably are found in group 4, which is supposed to be heterozygous for this regressive 6-rowed AAbb  $\times$  the 2-rowed aabb. On the other hand, group 3 is heterozygous for the parent 6-rowed AABB  $\times$  the 2-rowed aabb.

It will be seen in Table II that the plants obtained in each group came very close to the expectancy. The numbers of 6-rowed and 2-rowed forms produced coincide exactly with the expected numbers, while the number of fixed intermediates is only two greater than in the calculated ratio.

The nature of the factors is better discussed in connection with the description of the genetic classes which is given in Table II. It will be seen from the table that except in group 1 these various classes differ in appearance as well as in genetic constitution. In some instances the separations are easily made on appearance alone, while in others only a part of the plants belonging to a group can be easily identified. The first four groups have lateral florets, the lemmas of which bear awn points or awns of varying lengths. Group 1, of course, presents no difficulties, for 6-rowed segregates are unmistakable. Group 2 is almost as definite, for there are no other high-fertility segregates with small-kerneled, awn-pointed lateral florets. Group 3 is readily separated from group 2 by the lower fertility of the individuals in group 3. The sterile individuals of group 3, however, are easily confused with the individuals of group 4. Probably 80 per cent of such plants in group 3 can be identified by the more obtuse lemma tip on the lateral florets. Groups 5, 6, and 7 differ from the other groups in the absence of awns on the rounded tips of the lateral florets. These conditions are not absolute, in that an occasional floret may possess an awn. In this case, however, other florets on the same spike have the characteristic rounded obtuse tips. Group 5 is characterized by the possession of lateral florets which, even when sterile, are larger than those of the 2-rowed. Under field conditions higher fertility probably would have been present in the members of this group. When the  $F_2$  material was being studied, it was possible, however, to isolate the sterile spikes of *intermedium* forms by inspection. In group 6 the lateral florets of many individuals are

obviously larger than in the 2-rowed segregates, but as a rule they are not so large as in group 5. Groups 6 and 7 can be accurately separated only by the breeding test.

It will be seen, then, that although fertility is the basic distinction, it is expressed in other ways than in the production or nonproduction of kernels. Indeed, the percentage of fertility probably varies more with environment than do the morphological differences. Such variation, however, does not imply any lack of reliability of the fertility factors.

According to the factor hypothesis, the first four groups have the inherent possibility of producing 6-rowed segregates. Only plants belonging to these four groups have lateral florets the lemmas of which are awned or awn-pointed. The A factor, either as AA or Aa, is found only in these groups. This factor, then, must be associated with the possibility of awns. When A is homozygous, fully fertile, long-awned florets which develop kernels of normal size are produced. When A is heterozygous, all lateral florets are short-awned or awn-pointed. When homozygous, it is epistatic to B, the spike being normal 6-rowed irrespective of the condition B. When heterozygous, A has little effect on fertility, and the amount of fertility present in this case is in direct relation to B. The lateral florets of AaBB are quite fertile, those of AaBb occasionally so, while those of Aabb as a class are sterile. Aa may have a slight effect on fertility, for AaBB has a higher percentage of fertility than aaBB. The factor BB, then, is a fertility factor which at its highest expression produces a lower percentage of fertility than AA. It is not accompanied by the presence of awns. The lateral florets under its stimulation produce undersized kernels, the largest form of floret seeming to be associated with AA.

#### INDICATION OF A THIRD FACTOR

The presence of a third factor of fertility was first suggested by a study of the data in Table I. Column 2 of that table shows the percentage of fertility of the  $F_2$  parents. In group 2, three plants exhibited a much lower fertility than the other four. Since one of these was abnormal, there were, excluding this plant, two low-fertility and four high-fertility plants. It is difficult to measure the inheritance of these variations in this group. The percentage of fertility of the *intermedium* segregates in the  $F_3$  generation of four lines was studied. The  $F_3$  *intermedium* segregates of the others were missing. Three high-fertility lines gave almost identical fertility of 37+ per cent. One low-fertility line gave 29.5 per cent of fertility. In group 3, five out of twenty-five plants showed some fertility. The  $F_3$  plants were not studied for differences in percentage of fertility.

• In group 5, two out of seven plants had fertile lateral florets. In this group the progeny were studied carefully. This is the only group

where this can be done readily, because the others, where the differences in percentage of fertility occur, are heterozygous for one or both main factors. If there is a third factor, the  $F_2$  generation indicates that it is expressed here as a 1 to 3 ratio with the heterozygous forms indistinguishable from those homozygous for the absence of the factor. By the same reasoning, lines 10 and 95 in Table I, which showed fertility, should be homozygous for the presence of the factor and should exhibit a higher percentage of fertility than the progeny of the other five lines. The  $F_3$  progeny of lines 10 and 95 averaged 54.6 and 48.4 per cent of fertility in the lateral florets, while the progeny of the other lines were, respectively, 35.7, 33.2, 30.3, 25, and 17.8 per cent fertile.

The data indicating a third factor in fertility are summarized in Table III. The evidence at hand is not more than an indication of a minor factor, yet the material itself is far more suggestive of such a factor than the evidence.

TABLE III.—Summary of data indicating a third factor of fertility in the cross between Manchuria and Swanhals

| Group No. | Genetic constitution as shown by progeny.                 | Hypothetical formulas.              | Expected mendelian ratio. | Number of plants in group. | Expected number of plants by subgroups.                      | Number of plants obtained. |
|-----------|---|-------------------------------------|---------------------------|----------------------------|--|----------------------------|
| 2         | Heterozygous for 6-rowed $\times$ intermediate.....       | AaBBCC...<br>AaBBCc...<br>AaBBcc... | 2<br>4<br>2               | 6                          | $\left\{ \begin{array}{l} 2 \\ 4 \end{array} \right\}$       | 4                          |
| 3         | Heterozygous for 6-rowed $\times$ 2-rowed.....            | AaBbCC...<br>AaBbCc...<br>AaBbcc... | 4<br>8<br>4               | 25                         | $\left\{ \begin{array}{l} 6 \\ 15 \\ 6 \end{array} \right\}$ | 5<br>20                    |
| 4         | Heterozygous for regressive 6-rowed $\times$ 2-rowed..... | AabbCC...<br>AabbCc...<br>Aabbcc... | 2<br>4<br>2               | 10                         | $\left\{ \begin{array}{l} 3 \\ 5 \\ 3 \end{array} \right\}$  | 2<br>6<br>2                |
| 5         | Homozygous for intermediate.....                          | aaBBCC...<br>aaBBCc...<br>aaBBcc... | 1<br>2<br>1               | 7                          | $\left\{ \begin{array}{l} 2 \\ 4 \\ 2 \end{array} \right\}$  | 2<br>5                     |

## DISCUSSION OF RESULTS

### FIXED, INTERMEDIATE, II. INTERMEDIUM

Since the purpose of this study was to gain a better understanding of the occurrence of *H. intermedium*, this form is of greater interest here than any of the other segregates. From the standpoint of historical and present interest there are three questions which can now be answered. There is no doubt that such forms occur; they have been found to be stable; and in the particular cross reported here in detail the ratio of appearance is approximately 1 to 16.

The stability of this form was established by observations on intermediates obtained from several crosses. The field experiences fit in well

with the 2-factor hypothesis suggested. The stability of the homozygous intermediate has been thoroughly tested. Some of these have been grown since 1912 under widely varying conditions with no indication of reverting to either the 6-rowed or 2-rowed parental type. Many hybrids have been made with the *intermedium* form as one parent. There are complete records of the progeny of crosses on five 6-rowed and on two 2-rowed forms. No 2-rowed segregates appeared among the progeny of the 6-rowed  $\times$  *intermedium* crosses, and no 6-rowed segregates appeared among the progeny of the *intermedium*  $\times$  2-rowed crosses. Every hybrid studied so far indicates that *H. intermedium* has a genetic rank equal to *H. vulgare* or *H. distichon*.

In field culture there is always variation in the amount of fertility present in the lateral florets of the *intermedium* form. This is true even on a single plant. The earlier, better-nourished spikes in some strains may have as high as 90 per cent of the lateral florets fertile. The later spikes of the same plant usually have a diminishing percentage, while the last-appearing may have lateral florets which are entirely sterile. Such variations, however, are the result of variation in nutrition, for their progeny are uniformly *intermedium* in type.

There are variations of another sort in the *intermedium* forms which have more significance. Frequent mention has been made of the fact that the fertility of the different classes may be expected to vary with the parents used. From crosses showing more vigor in the lateral florets of the segregates than those of the Manchuria  $\times$  Svanhals, very vigorous intermediates may be isolated. From those crosses which show less fertility in the segregates, homozygous intermediates probably may be isolated in which only occasional kernels may be produced. Instances may be possible where a potential intermediate may exhibit no fertility whatever.

The form *atlerbergii* shown in Plate 106 is probably an infertile *intermedium* barley. This form is somewhat anomalous in the taxonomy of barley. It has never been grown by the authors, but from the statements of those who have grown it, it appears to have shown no fertility. The illustration is a photograph of a spike presented to the United States Department of Agriculture several years ago by Mr. E. S. Beaven. It has greatly enlarged lateral florets which closely resemble those of spikes of *H. intermedium*, in which potentially fertile lateral florets are sterile because of environment.

#### REGRESSIVE 6-ROWED FORM

The recognition of the two different forms homozygous for the 6-rowed character offers a field for further investigation. The regressive 6-rowed AAbb is apparently not optically distinguishable from the AABb 6-rowed. There is no method known to the authors of separating these by inspection. In hybrids the regressive 6-rowed form should behave quite



differently. If this regressive type were crossed on the *intermedium* form the results, according to the hypothesis advanced, would not be the same as when the Manchuria is so crossed. The Manchuria  $\times$  *intermedium* gives 6-rowed, high-fertility, and *intermedium* segregates in a 1 to 2 to 1 ratio in the  $F_2$  generation. The regressive 6-rowed  $\times$  the *intermedium* form should give all classes, including 2-rowed forms, in the  $F_2$  generation. On the other hand, if the regressive 6-rowed were crossed on the Svanhals, no *intermedium* segregates would be expected. Unfortunately, neither of these crosses has been made, but the latter condition has been met in other crosses. Strains of Odessa and Reid Triumph when crossed on Svanhals produced no intermediates, indicating that the regressive 6-rowed AAbb does occur. The progeny of these crosses segregates in the same way as the group which is heterozygous for the regressive 6-rowed  $\times$  2-rowed in Table I. Incidentally, there is evidence that the strains used, of both Reid Triumph and Odessa, originated as selections from a previous hybridization. No evidence is at hand to indicate whether or not the regressive 6-rowed type AAbb occurs elsewhere than in the progeny of hybrids.

Because fixed intermediates have been secured from hybrids in which several old agricultural races of 6-rowed barley were used as one parent, it is assumed that forms such as the Manchuria are the normal 6-rowed forms. It is not known how frequently the regressive types occur among our agricultural sorts, nor whether they are associated with other characters than the failure to produce intermediates. Heritable variations in the amount of fertility in the lateral florets of 6-rowed barleys have been noticed, however, and since the conception of a regressive 6-rowed type offers a possible explanation of their behavior, a statement concerning these unusual varieties may be of interest.

In 1909 the senior author noticed a decided tendency to sterility of lateral florets in the agronomic varieties known as Mansfield and Summit. In each case the earliest spikes to appear were normal 6-rowed spikes. The lateral florets were highly fertile, long awned, and produced large kernels. In the later spikes, especially where the plants produced several culms, the lateral florets exhibited increasing sterility. Late spikes, in which none of the lateral florets were fertile, were found in many plants. One of these barleys, Mansfield, was the progeny of a cross between a 6-rowed and a 2-rowed barley, made at Guelph, Ont., in 1891. The peculiar behavior of this variety was so striking that selections of fertile and infertile spikes were made in 1909. These were planted in 1910, but, as would be expected, there was no difference in their inheritance. Owing to seasonal conditions the percentage of spikes with no fertility in the lateral florets was unusually large in 1910, the sterile spikes being approximately equal to the fertile in number. Spikes from a single plant are shown in Plate 105, D. It will be seen that the sterile florets are

long awned and that there is no approach toward the homozygous intermediate. The second variety, Summit, which for other reasons is thought also to be of hybrid origin, produced spikes with infertile lateral florets much more rarely. It is suggested that these barleys may be forms of the 6-rowed segregate A.Abbcc, homozygous for the absence of the two secondary factors of fertility.

#### POSITION OF FERTILE LATERAL SPIKELETS

Aside from the question of the amount of fertility in the lateral florets, the location of fertile florets on the spike is of interest. In the common varieties of barley the largest kernels are produced about one-third of the distance from the base of the spike to the tip, in both the central and the lateral spikelets. The longest awns are attached to these florets, and they exhibit a progressive decrease in length toward the tip of the spike. The fertility of the homozygous intermediate runs in the reverse order. When only a few kernels are produced they are found in the upper third and gradually extend downward from the tip in the more fertile intermediates. The most fertile lateral florets in the Mansfield variety are found near the center of the spike.

#### ABERRANT LINE NO. 37

In Table I line No. 37 was found to differ greatly from the other members of group 2 in both appearance and fertility. It is much lower in fertility than the other individuals and, with the exception of one or two florets, is similar in appearance to the fixed intermediate. This plant is the only one of the 87 whose appearance is difficult to explain. It is not believed that the hypothesis of its being homozygous for the absence of the third factor is adequate explanation for its wide departure from type. For this reason this line was excluded in the later discussion. It is possible that the supposed  $F_2$  plant is the result of a natural hybrid. The appearance of the forms in any class varies with the parents used. Some combinations result in greater fertility in the various classes, others result in much less. If the  $F_1$  kernel from which this  $F_2$  plant developed had been fertilized by some neighboring 6-rowed variety less vigorous than the Manchuria or by a low-fertility *intermedium* form, such a plant as No. 37 might result. The opportunity for accidental crossing in the  $F_1$  generation is unusually good. The lateral florets of the  $F_1$  plants are much more likely to open at flowering time than are the normal barley florets, and they flower after the spike is exerted. The flowering glumes are less interlocked and open more readily and more widely. The flowers are more frequently deficient in pollen, and those not self-pollinated remain open for hours or even days, affording unusual opportunity for cross pollination.

## SUMMARY

*H. intermedium* is a form of barley in which the awnless lateral florets exhibit a fertility greater than that found in the 2-rowed and less than that occurring in the 6-rowed barleys.

The occurrence of this form as a homozygote has been questioned frequently.

*H. intermedium* forms which are stable under all conditions of culture have been isolated from numerous crosses reported in this paper. This form appears to be genetically as distinct as either *H. vulgare* or *H. distichon*.

A 2-factor hypothesis for fertility in the lateral florets is suggested. On the presence-and-absence hypothesis the 6-rowed barleys are supposed to be homozygous for the presence of the epistatic factor, the *intermedium* to be homozygous for the presence of the hypostatic factor and for absence of the epistatic factor, and the Svanhals to be homozygous for the absence of both factors.

According to the hypothesis, there are two types of 6-rowed barleys. The Manchuria parent is supposed to be homozygous for the presence of both factors, while certain regressive 6-rowed segregates are thought to be homozygous for the presence of the epistatic factor and for the absence of the hypostatic factor.

There is evidence suggestive of a third factor which affects the vigor of the lateral florets and their percentage of fertility.

## LITERATURE CITED

- (1) BIFFIN, R. H.  
1907. THE HYBRIDIZATION OF BARLEYS. *In Jour. Agr. Sci.*, v. 2, pt. 2, p. 183-206.
- (2) HARLAN, Harry V.  
1918. THE IDENTIFICATION OF VARIETIES OF BARLEY. U. S. Dept. Agr. Bul. 622, 32 p., 4 pl. Literature cited, p. 31-32.
- (3) H[AXTON], J[ohn].  
1851. BARLEY. *In* Morton, John C., ed. *Cyclopaedia of Agriculture* . . . v. 1, p. 176-191. Glasgow, Edinburgh, London.  
Article is signed "J. H." and is credited by Körnicke to Haxton. See following reference, p. 173.
- (4) KÖRNICKE, Friedr.  
1885. DIE ARTEN UND VARIETÄTEN DES GETREIDES. 470 p., 10 pl. Berlin. (Körnicke, Friedr., and Werner, Hugo. *Handbuch des Getreidebaues*. v. 1.)
- (5) ———  
1908. DIE ENTSTEHUNG UND DAS VERHALTEN NEUER GETREIDEVARIETÄTEN. Hrsg. von M. Körnicke. *In Arch. Biontol.*, Bd. 2, Heft 2, p. 389-437.
- (6) RIMPAU, Wilhelm.  
1891. KREUZUNGSPRODUKTE LANDWIRTSCHAFTLICHER KULTURPFLANZEN. *In Landw. Jahrb.*, Bd. 20, p. 335-371.
- (7) ———  
1892. DIE GENETISCHE ENTWICKELUNG DER VERSCHIEDENER FORMEN UNSERER SAATGERSTE. *In Landw. Jahrb.*, Bd. 21, p. 699-702.

(8) TSCHERMAK, Erich von.

1914. DIE VERWERTUNG DER BASTARDIERUNG FÜR PHYLOGENETISCHE FRAGEN  
IN DER GETREIDEGRUPPE. In Ztschr. Pflanzenzücht., Bd. 2, Heft 3,  
p. 291-312.

(9) WILSON, John H.

1907. THE HYBRIDIZATION OF CEREALS. In Jour. Agr. Sci., v. 2, pt. 1, p. 68-88,  
pl. 1.

PLATE 103

Individual heads representing the three phenotypic progeny classes in which the lateral florets bear awns:

A.—Low-fertility class.

B.—High-fertility class.

C.—Manchuria parent representing the 6-rowed segregates.

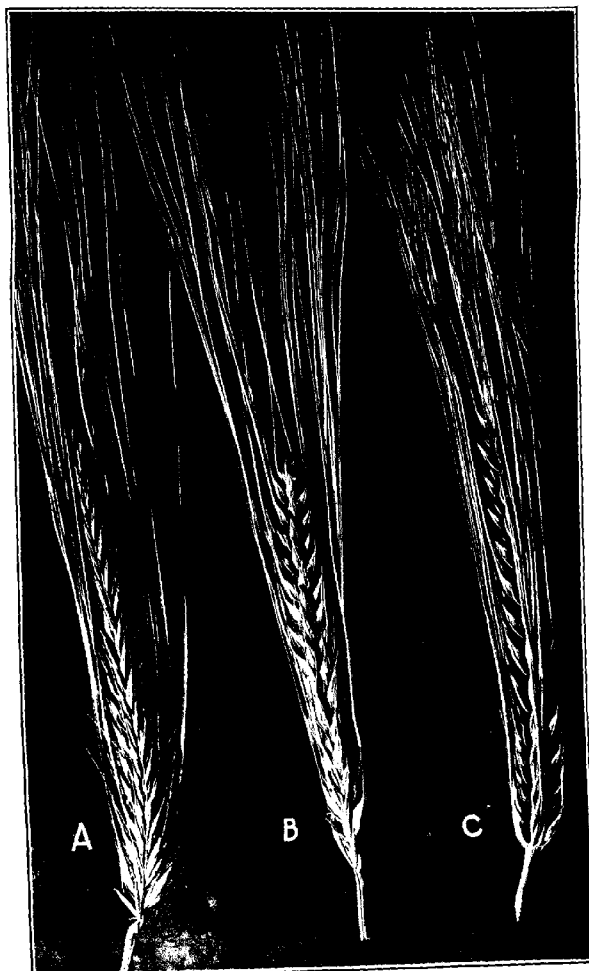




PLATE 104

Individual heads representing the phenotypic progeny classes in which the lemmas  
of the lateral florets are rounded and awnless:

A.—The 2-rowed, represented here by the Svanhals parent.

B.—Low-fertility class.

C.—*Hordeum intermedium*.



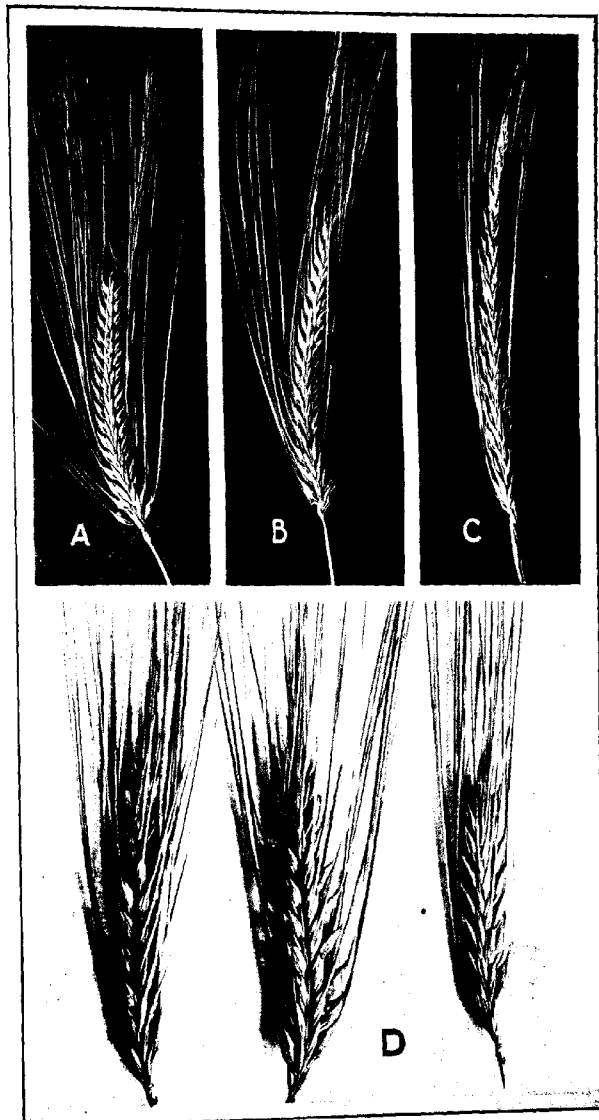
PLATE 105

A.—Awn-pointed individual, heterozygous for regressive 6-rowed and 2-rowed characters.

B.—Short-awned individual, heterozygous for regressive 6-rowed and 2-rowed characters.

C.—Long-awned individual, heterozygous for regressive 6-rowed and 2-rowed characters.

D.—Three spikes of Mansfield barley from the same plant, showing the variations of fertility in the lateral florets.



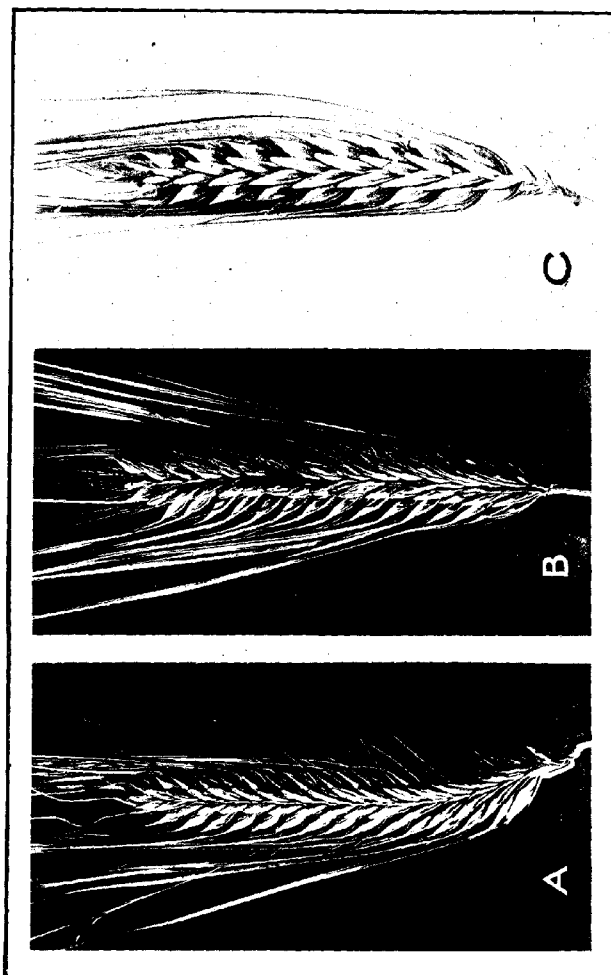


PLATE 106

- A.—Infertile spike of potentially fertile *Hordeum intermedium*.  
B.—Fertile spike of *H. intermedium*.  
C.—Var. *atterbergii*, probably a sterile *intermedium*.

ADDITIONAL COPIES  
OF THIS PUBLICATION MAY BE PROCURED FROM  
THE SUPERINTENDENT OF DOCUMENTS  
GOVERNMENT PRINTING OFFICE  
WASHINGTON, D. C.  
AT  
20 CENTS PER COPY  
SUBSCRIPTION PRICE, \$1.50 PER YEAR  
▽





# INDEX

|  | Page         |   | Page              |
|--|--------------|---|-------------------|
| A-amino nitrogen in frozen wheat.....  | 185-186      | Anias. See <i>Andropogon sorghum</i> , var. <i>halapensis</i> .   |                   |
| Acid—  |              | Anthony, Stephen, and Harlan, Harry V. (paper): Development of Barley Kernels in Normal and Clipped Spikes and the Limitations of Awnless and Hooded Varieties..... | 431-472           |
| citric, effect on germination and growth.....                                | 74-96        | Antigens, germ-free filtrates.....  | 513-515           |
| malic, in Bartlett pears.....  | 482-499      | Antimony, black sulphid, effect on milk and fat production.....   | 125-130           |
| phosphoric—  |              | Aphis, corn. See <i>Aphis maidis</i> .  |                   |
| effect of sulphur on release in greensand.....                               | 241          | <i>Aphis maidis</i> , carrier of sugar-cane mosaic.....   | 133-135           |
| effect on germination and growth.....  | 74-96        | <i>Aristida longistola</i> on northern Great Plains.....  | 65-72             |
| Acid-hydrolyzable substances in Bartlett pears.....                          | 480-499      | Arsenic, effect on milk and fat production.....   | 125-130           |
| Acidity—   |              | <i>Artemisia—</i>   |                   |
| effect on persistence of <i>Pseudomonas citri</i> in soil.....               | 217-218      | <i>dracunculoides</i> on northern Great Plains.....   | 65-72             |
| of Bartlett pears.....   | 489-494      | <i>frigida</i> on northern Great Plains.....  | 65-72             |
| of greensand.....  | 245-255      | <i>gnaaphalodes</i> on northern Great Plains.....   | 65-72             |
| of silage.....   | 174-176      | Artificial and Insect Transmission of Sugar-Cane Mosaic (paper).....  | 131-138           |
| of wheat, effect of freezing.....  | 187-188      | Ash content of barley kernels—  |                   |
| Acids, toleration by <i>Bacterium coronafaciens</i> .....                    | 152-153      | change during development.....  | 412-428           |
| <i>Aegle marmelos</i> , susceptibility to <i>Pseudomonas citri</i> .....     | 341-349, 345 | from normal and clipped spikes.....   | 452-469           |
| <i>Aeglinae</i> , susceptibility to <i>Pseudomonas citri</i> .....           | 341-342      | Ashby, R. C. and Malcolmson, A. W. (paper): Variation of Individual Pigs in Economy of Gain.....  | 225-234           |
| <i>Aegolopsis Chevalleri</i> , immunity to <i>Pseudomonas citri</i> .....    | 347-348      | <i>Aster multiflorus</i> on northern Great Plains.....  | 65-72             |
| Aerobism of <i>Bacterium coronafaciens</i> .....                             | 157-158      | <i>Atalanta—</i>  |                   |
| <i>Agropyron—</i>  |              | <i>Ceylonica</i> , susceptibility to <i>Pseudomonas citri</i> .....   | 343-345, 347      |
| <i>caninum—</i>  |              | <i>citrioides</i> , susceptibility to <i>Pseudomonas citri</i> .....  | 343-345, 347, 348 |
| host of <i>Puccinia glumarum</i> .....                                       | 258          | <i>disticha</i> , susceptibility to <i>Pseudomonas citri</i> .....  | 348               |
| on northern Great Plains.....  | 65-72        | <i>glauca</i> . Syn. <i>Eremocitrus glauca</i> .  |                   |
| <i>repens</i> , host of <i>Puccinia coronata agropyri</i> .....              | 258          | <i>Hindii</i> . Syn. <i>Fortunella Hindii</i> .   |                   |
| <i>smithii</i> on northern Great Plains.....                                 | 65-72        | <i>Asterbergii</i> , variety, infertile intermediate barley.....  | 587               |
| <i>tenerum</i> on northern Great Plains.....                                 | 65-72        | <i>Avena sativa</i> , halo-blight.....  | 139-172           |
| Aguin gay. See <i>Ratibollia exaltata</i> .                                  |              | Awnless barley, limitations.....  | 431-472           |
| Alang-alang grass. See <i>Imperata</i> sp.                                   |              | <i>Bacillus—</i>  |                   |
| Alcohol—   |              | <i>avenae</i> , causal organism of blade-blight of oats.....  | 167               |
| effect on milk and fat production.....                                       | 124          | <i>botulinus</i> , separation by germ-free filtrates.....   | 513-515           |
| in silage.....   | 174-177      | <i>edemotensis</i> , separation by germ-free filtrates.....   | 513               |
| Alcohol-insoluble substances in Bartlett pears.....                          | 480-499      | <i>leuconus</i> , separation by germ-free filtrates.....  | 513               |
| Alkalinity, effect on persistence of <i>Pseudomonas citri</i> in soil.....   | 217-218      | <i>Bacterium coronafaciens</i> , n. sp.—  |                   |
| Alcoes, effect on milk and fat production.....                               | 124          | control.....  | 170-172           |
| Aluminum—  |              | cultural characters.....  | 148-158           |
| oxid in greensand.....   | 244          | description of lesions.....   | 159-160           |
| sulphate, effect on availability of potassium of greensand.....              | 242-256      | geographical distribution.....  | 149               |
| Amid nitrogen in frozen wheat.....   | 185-186      | isolation No. 36.....   | 154-155           |
| Ammonia nitrogen in frozen wheat.....  | 185-186      | overwintering and dissemination.....  | 158-162           |
| Ammonia production by <i>Bacterium coronafaciens</i> .....                   | 151          | stock halo organism.....  | 148-154           |
| <i>Andropogon—</i>   |              | yellow organism.....  | 155-158           |
| <i>furcatus</i> on northern Great Plains.....                                | 66-72        | <i>Balsamocitrus Daves</i> , immunity to <i>Pseudomonas citri</i> .....   | 343-345           |
| <i>scofariis</i> on northern Great Plains.....                               | 65-72        |   |                   |
| <i>sorghum—</i>  |              |   |                   |
| host of <i>Sclerospora philippinensis</i> .....                              | 104-112      |   |                   |
| var. <i>halapensis</i> resistance to <i>Sclerospora philippinensis</i> ..... | 104          |   |                   |



|  | Page    |  | Page               |
|--|---------|--|--------------------|
| Banana Root-Borer (paper).....   | 39-46   | Carbonate, calcium, effect on availability of potassium of greensand.....          | 242-256            |
| Barley kernels, development—   |         | Carex—   |                    |
| daily.....   | 393-430 | <i>filifolia</i> on northern Great Plains.....                                     | 65-72              |
| in normal and clipped spikes.....  | 431-473 | <i>halophila</i> on northern Great Plains.....                                     | 65-72              |
| Bartlett pears, ripening and storage.....  | 473-500 | <i>Casimiroa edulis</i> , susceptibility to <i>Pseudomonas citri</i> .....         | 341-346            |
| <i>Bacterium translucens</i> var. <i>undulorum</i> , effect of—  |         | Castor oil, effect on milk and fat production.....                                 | 124                |
| formalin.....  | 366-379 | <i>Chaetospermum glutinosum</i> , susceptibility to <i>Pseudomonas citri</i> ..... | 342, 345, 346, 348 |
| presoak method.....  | 379-392 | <i>Chaetochloa lutescens</i> , susceptibility to sugar-cane mosaic.....            | 134                |
| <i>Beckmannia cruciformis</i> , host of <i>Puccinia coronata</i> .....   | 257     | <i>Chalcas exotica</i> , susceptibility to <i>Pseudomonas citri</i> .....          | 347-346            |
| Beetles—   |         | Chlorid, calcium, effect on germination and growth.....                            | 74-96              |
| Colorado potato. See <i>Leptinotarsa decemlineata</i> .  |         | Citrangle, susceptibility to <i>Pseudomonas citri</i> .....                        | 355                |
| flea. See <i>Epitrix cucumeris</i> .   |         | Citradia, susceptibility to <i>Pseudomonas citri</i> .....                         | 354                |
| Behavior of the Citrus-Canker Organism in the Soil (paper).....  | 189-206 | Citrandarin, susceptibility to <i>Pseudomonas citri</i> .....                      | 354-355            |
| Bicarbonate, sodium, effect on milk and fat production.....  | 125-130 | Citrangarin, susceptibility to <i>Pseudomonas citri</i> .....                      | 355                |
| Bigaradin, susceptibility to <i>Pseudomonas citri</i> .....  | 356     | Citrangle, susceptibility to <i>Pseudomonas citri</i> .....                        | 354                |
| Black raspberry, host of <i>Gymnoconia interstitialis</i> .....  | 501-507 | Citrangedin, susceptibility to <i>Pseudomonas citri</i> .....                      | 355                |
| Blackberry, host of <i>Gymnoconia interstitialis</i> .....   | 505-506 | Citrangedin, susceptibility to <i>Pseudomonas citri</i> .....                      | 355                |
| Blackleg filtrates, germ-free.....   | 513-515 | Citrangestat, susceptibility to <i>Pseudomonas citri</i> .....                     | 356                |
| Blish, M. J. (paper): Effect of Premature Freezing on Composition of Wheat.....  | 181-188 | Citranguma, susceptibility to <i>Pseudomonas citri</i> .....                       | 356                |
| Blue grama. See <i>Bouteloua gracilis</i> .  |         | Citric acid. See Acid, citric.   |                    |
| <i>Bouteloua</i> —   |         | <i>Citropsis Schweinfurthii</i> , susceptibility to <i>Pseudomonas citri</i> ..... | 343, 345, 347, 348 |
| <i>curtipendula</i> on northern Great Plains.....  | 65-72   | Citrumelo, susceptibility to <i>Pseudomonas citri</i> .....                        | 354                |
| <i>gracilis</i> on northern Great Plains.....  | 65-72   | Citrunshu, susceptibility to <i>Pseudomonas citri</i> .....                        | 355                |
| <i>Brachypodium pinnatum</i> , host of <i>Puccinia glumarum</i> .....  | 258     | Citrus-canker. See <i>Pseudomonas citri</i> .                                      |                    |
| Brandes, E. W. (paper)—  |         | Citrus—  |                    |
| Artificial and Insect Transmission of Sugar-Cane Mosaic.....   | 131-138 | <i>aurantifolia</i> —  |                    |
| Mosaic Disease of Corn.....  | 517-522 | infection resembling <i>Pseudomonas citri</i> .....                                | 203-204            |
| Braun, Harry (paper): Presoak Method of Seed Treatment: A Means of Preventing Seed Injury Due to Chemical Disinfectants and of Increasing Germicidal Efficiency..... | 203-392 | susceptibility to <i>Pseudomonas citri</i> .....                                   | 350-361            |
| <i>Bromus mollis</i> , host of <i>Puccinia glumarum</i> .....  | 258     | <i>australasica</i> . Syn. <i>Microcitrus australasica</i> .                       |                    |
| Buffalo grass. See <i>Bulbils dactyloides</i> .  |         | <i>australis</i> . Syn. <i>Microcitrus australis</i> .                             |                    |
| <i>Bulbils dactyloides</i> on northern Great Plains.....   | 66-72   | <i>decumana</i> . Syn. <i>Citrus maxima</i> .                                      |                    |
| <i>Calamovilfa longifolia</i> on northern Great Plains.....  | 65-72   | <i>exelsa</i> , susceptibility to <i>Pseudomonas citri</i> .....                   | 352-361            |
| <i>Calandra sordida</i> . Syn. <i>Cosmophilus sordida</i> .  |         | <i>Garrowayi</i> . Syn. <i>Microcitrus Garrowayi</i> .                             |                    |
| Calarin, susceptibility to <i>Pseudomonas citri</i> .....  | 358     | <i>grandis</i> —   |                    |
| Calashu, susceptibility to <i>Pseudomonas citri</i> .....  | 358     | susceptibility to <i>Pseudomonas citri</i> .....                                   | 350-361            |
| Calcium—   |         | Syn. <i>Citrus maxima</i> .  |                    |
| carbonate, effect on availability of potassium of greensand.....   | 242-256 | <i>hystris</i> , susceptibility to <i>Pseudomonas citri</i> .....                  | 349-361            |
| chlorid, effect on germination and growth.....   | 74-96   | <i>japonica</i> . Syn. <i>Fortunella japonica</i> .                                |                    |
| acid in greensand.....   | 244     | <i>limetta</i> . See <i>Citrus aurantiifolia</i> .                                 |                    |
| phosphate, effect on solubility of soils.....  | 50-51   | <i>margarita</i> . Syn. <i>Fortunella margarita</i> .                              |                    |
| sulphate, effect on solubility of soils.....   | 47-54   | <i>maxima</i> , effect of inoculation with <i>Pseudomonas citri</i> .....          | 190-199            |
| Caraway, effect on milk and fat production.....  | 125-130 | <i>medica</i> , susceptibility to <i>Pseudomonas citri</i> .....                   | 349                |
| Carbohydrates—   |         | <i>mitis</i> , susceptibility to <i>Pseudomonas citri</i> .....                    | 351-361            |
| in silage.....   | 174-178 | <i>nobilis</i> —   |                    |
| in wheat, effect of freezing.....  | 186-187 | var. <i>unshiu</i> , susceptibility to <i>Pseudomonas citri</i> .....              | 349-361            |
| Carbon dioxide, effect of calcium sulphate on production in soil.....  | 51-53   | susceptibility to <i>Pseudomonas citri</i> .....                                   | 351-361            |

## Citrus—Continued.

|   | Page     |  | Page          |
|---|----------|--|---------------|
| <i>sinensis</i> —   |          | Drugs, effect on milk and fat production...  | 123-130       |
| effect of inoculation with <i>Pseudomonas citri</i> .....   | 293-294  | Dry matter in kernels from normal and clipped barley spikes.....                                   | 452-469       |
| susceptibility to <i>Pseudomonas citri</i> .....  | 350-361  | <i>Echinacea angustifolia</i> on northern Great Plains.....  | 65-72         |
| <i>trifoliata</i> —   |          | Effect of Calcium Sulphate on the Solubility of Soils (paper).....                                 | 47-54         |
| effect of inoculation with <i>Pseudomonas citri</i> .....   | 200-202  | Effect of Drugs on Milk and Fat Production (paper).....  | 123-130       |
| Syn. <i>Poncirus trifoliata</i> .   |          | Effect of Manure-Sulphur Composts upon the Availability of the Potassium of Greensand (paper)..... | 239-256       |
| <i>Claucaena lanarium</i> , susceptibility to <i>Pseudomonas citri</i> .....  | 341-346  | Effect of Premature Freezing on Composition of Wheat (paper).....                                  | 181-188       |
| Clemelo, susceptibility to <i>Pseudomonas citri</i> .....   | 357      | Effect of Reaction of Solution on Germination of Seeds and on Growth of Seedlings (paper).....     | 73-96         |
| Clonal varieties of Irish potatoes.....   | 543-573  | <i>Eleusine coracana</i> , effect of field heterogeneity on yield.....                             | 291-294       |
| Cocoa. See <i>Imperata cylindrica</i> .   |          | Elliott, Charlotte (paper): Halo-Blight of Oats.....   | 139-172       |
| Coix—   |          | <i>Elymus canadensis</i> , host of <i>Puccinia montensis</i> .....                                 | 257           |
| <i>lachryma-jobi</i> , resistance to <i>Sclerospora philippinensis</i> .....  | 104      | <i>Epitrix cucumeris</i> , failure to transmit potato mosaic.....                                  | 320           |
| <i>ma yuen</i> , resistance to <i>Sclerospora philippinensis</i> .....  | 104      | Epsom salts, effect on milk and fat production.....  | 124           |
| Collins, G. N., and Kempton, J. H. (paper): A Teosinte-Maize Hybrid.....  | 1-38     | <i>Eremocitrus gleuca</i> , susceptibility to <i>Pseudomonas citri</i> .....                       | 344, 345, 347 |
| Colorado potato beetles. See <i>Leptinotarsa decemlineata</i> .   |          | <i>Euchlaena</i> —   |               |
| <i>Comandra pallida</i> on northern Great Plains.....   | 65-72    | <i>luscians</i> , host of <i>Sclerospora philippinensis</i> .....                                  | 104-122       |
| Complement-fixation test, germ-free filtrates as antigens.....  | 513-515  | <i>sis</i> , hybrid with maize.....  | 1-38          |
| Composition and Density of the Native Vegetation in the Vicinity of the Northern Great Plains Field Station (paper).....    | 63-72    | <i>Euphorbia dentata</i> , host of <i>Uromyces euphorbiae</i> .....                                | 259           |
| Composts, manure-sulphur, effect on availability of potassium of greensand.....   | 239-256  | <i>Evodia</i> —  |               |
| Conidia, production in <i>Gibberella saubinetii</i> .....   | 235-237  | <i>latifolia</i> , susceptibility to <i>Pseudomonas citri</i> .....                                | 345, 346      |
| Copper sulphate, prevention of injury to seeds by presoak method.....   | 363-392  | <i>ridgelyi</i> , susceptibility to <i>Pseudomonas citri</i> .....                                 | 345, 346      |
| Corn. See <i>Zea mays</i> .   |          | "False hybrids," susceptibility to <i>Pseudomonas citri</i> .....                                  | 359           |
| Corn aphids. See <i>Aphis maidis</i> .  |          | Fat production in milk, effect of drugs.....   | 123-130       |
| <i>Cosmopolites sordidus</i> —  |          | Faustrime, susceptibility to <i>Pseudomonas citri</i> .....  | 354           |
| control.....  | 45-46    | Faustrimon, susceptibility to <i>Pseudomonas citri</i> .....                                       | 354           |
| description.....  | 41-44    | Faustrimedlin, susceptibility to <i>Pseudomonas citri</i> .....                                    | 354           |
| history and distribution.....   | 39-40    | Fennel, effect on milk and fat production.....   | 123-130       |
| hosts.....  | 40-41    | Fermentation, influence on the starch content of experimental silage.....                          | 173-179       |
| life history.....   | 44-45    | <i>Feronia</i> —   |               |
| Crabgrass. See <i>Syntherisma sanguinalis</i> .   |          | <i>elephantum</i> . Syn. <i>Feronia limonia</i> .  |               |
| Daily Development of Kernels of Hannchen Barley from Flowering to Maturity at Aberdeen, Idaho (paper).....                  | 393-430  | <i>limonia</i> , susceptibility to <i>Pseudomonas citri</i> .....                                  | 342, 345      |
| Decline of <i>Pseudomonas citri</i> in the Soil (paper).....  | 207-223  | Feroninae, susceptibility to <i>Pseudomonas citri</i> .....  | 342           |
| Development of Barley Kernels in Normal and Clipped Spikes and the Limitations of Awnless and Hooded Varieties (paper)..... | 431-472  | <i>Feroniella lucida</i> , susceptibility to <i>Pseudomonas citri</i> .....                        | 342, 345, 347 |
| Dewberry, host of <i>Gymnocrania interstitialis</i> .....   | 505-506  | Ferric acid in greensand.....  | 244           |
| Dextrin and soluble starch in frozen wheat.....   | 187      | Ferrous sulphate, effect on availability of potassium of greensand.....                            | 242-256       |
| Dickson, James G., and Johann, Helen (paper): Production of Conidia in <i>Gibberella saubinetii</i> .....                   | 235-237  | Fiber, wool, influence of humidity on strength and elasticity.....                                 | 55-62         |
| Dioxid, carbon, effect of calcium sulphate on production in soil.....   | 51-52    | Filtrates, germ free, in complement-fixation test.....   | 513-515       |
| Dipotassium phosphate, effect on germination and growth.....  | 74-96    |  |               |
| Downy mildew of maize. See <i>Sclerospora philippinensis</i> .  |          |  |               |
| Dox, Arthur W., and Yoder, Lester (paper): Influence of Fermentation on the Starch Content of Experimental Silage.....      | 173-179  |  |               |
| <i>Dracontolopha molipes</i> , failure to carry sugar-cane mosaic.....  | 134, 135 |  |               |

|   | Page               |   | Page               |
|---|--------------------|---|--------------------|
| Fixed intermediate in barley crosses.....                 | 575-598            | Halo-Blight of Oats (paper).....                              | 339-372            |
| Flea beetles. See <i>Epidius cucumeris</i> .              |                    | Hannchen barley, daily development of                         |                    |
| Folsom, Donald, and Schultz, E. S. (paper):               |                    | kernels.....  | 393-430            |
| Transmission of the Mosaic Disease of Irish               |                    | Hardy, J. I. (paper): Further Studies on the                  |                    |
| Potatoes.....   | 375-338            | Influence of Humidity upon the Strength                       |                    |
| Formalin, prevention of injury to seeds by                |                    | and Elasticity of Wool Fiber.....                             | 55-62              |
| presoak method.....                                       | 363-392            | Harlan, Harry V. (paper): Daily Develop-                      |                    |
| <i>Fortunella</i> —                                       |                    | ment of Kernels of Hannchen Barley from                       |                    |
| <i>crassifolia</i> , susceptibility to <i>Pseudomonas</i> |                    | Flowering to Maturity at Aberdeen,                            |                    |
| <i>citri</i> .....  | 344, 345           | Idaho.....  | 393-430            |
| <i>Hindii</i> , susceptibility to <i>Pseudomonas</i>      |                    | Harlan, Harry V., and Anthony, Stephen                        |                    |
| <i>citri</i> .....  | 344, 345, 347, 348 | (paper): Development of Barley Kernels                        |                    |
| <i>jaпонica</i> , susceptibility to <i>Pseudomonas</i>    |                    | in Normal and Clipped Spikes and the                          |                    |
| <i>citri</i> .....  | 344, 345, 348      | Limitations of Awnless and Hooded Vari-                       |                    |
| <i>margarita</i> , susceptibility to <i>Pseudomonas</i>   |                    | eties.....  | 431-472            |
| <i>citri</i> .....  | 344, 345, 348      | Harlan, Harry V., and Hayes, H. K. (paper):                   |                    |
| Footail. See <i>Chaetochloa lutescens</i> .               |                    | Occurrence of the Fixed Intermediate,                         |                    |
| Frederich, William J., and Peltier, George L.             |                    | Hordeum intermedium haxtoni, in Crosses                       |                    |
| (paper): Relative Susceptibility to Citrus                |                    | between <i>H. vulgare pallidum</i> and <i>H. distichon</i>    |                    |
| Canker of Different Species and Hybrids of                |                    | palmella.....   | 575-592            |
| the Genus Citrus, Including the Wild Rela-                |                    | Harris, Arthur J. (paper): Practical Univer-                  |                    |
| tives.....  | 339-362            | sality of Field Heterogeneity as a Factor                     |                    |
| Freezing, effect on—                                      |                    | Influencing Plot Yields.....                                  | 279-324            |
| <i>Bacterium coronafaciens</i> .....                      | 253                | Hayes, H. K., and Harlan, Harry V. (paper):                   |                    |
| composition of wheat.....                                 | 181-188            | Occurrence of the Fixed Intermediate,                         |                    |
| Fulton, H. R. (paper): Decline of <i>Pseudo-</i>          |                    | Hordeum intermedium haxtoni, in Crosses                       |                    |
| monas citri in the Soil.....                              | 207-223            | between <i>H. vulgare pallidum</i> and <i>H. distichon</i>    |                    |
| Further Data on the Orange-Rusts of Rubus                 |                    | palmella.....   | 575-592            |
| (paper).....  | 501-519            | Hayes, H. K., Parker, John H., and Kurtz-                     |                    |
| Further Studies on the Influence of Humidity              |                    | well, Carl (paper): Genetics of Rust Resist-                  |                    |
| upon the Strength and Elasticity of Wool                  |                    | ance in Crosses of Varieties of Triticum vul-                 |                    |
| Fiber (paper).....  | 55-62              | gare with Varieties of <i>T. durum</i> and <i>T.</i>          |                    |
| Gas formation of <i>Bacterium coronafaciens</i> ...       | 157-158            | dicoccum.....   | 523-524            |
| Genetics of Rust Resistance in Crosses of                 |                    | Hays, Frank A., and Thomas, Merton C.                         |                    |
| Varieties of Triticum vulgare with Varieties              |                    | (paper): Effect of Drugs on Milk and Fat                      |                    |
| of <i>T. durum</i> and <i>T. dicoccum</i> (paper).....    | 523-524            | Production.....   | 123-130            |
| Genetics, teosinte-maize hybrid.....                      | 1-38               | <i>Hesperibius crenulata</i> , susceptibility to              |                    |
| Gentian, effect on milk and fat production...             | 125-130            | <i>Pseudomonas citri</i> .....                                | 343, 345, 347, 348 |
| Germ-Free Filtrates as Antigens in the Com-               |                    | Heterogeneity in fields—                                      |                    |
| plement-Fixation Test (paper).....                        | 513-515            | influence on yield of—  |                    |
| Germination of—   |                    | alfalfa hay.....  | 286-291            |
| <i>Gymnocris interstitialis</i> , influence of tem-       |                    | corn.....   | 296-299            |
| perature.....   | 502-503            | hops.....   | 295                |
| seeds, effect of reaction of solution.....                | 73-96              | kherson oats.....   | 294                |
| wheat, effect of formalin.....                            | 366-379            | mangolds.....   | 284                |
| <i>Gibberella subimmetit</i> , production of conidia...   | 235-237            | nitrogen content of wheat.....                                | 294-295            |
| Ginger, effect on milk and fat production...              | 125-130            | orchard crops.....  | 299-300            |
| Glucose in Bartlett pears.....                            | 483-499            | potatoes.....   | 284-286            |
| <i>Glycormis pentaphylla</i> , immunity to <i>Pseudo-</i> |                    | ragi.....   | 291-294            |
| monas citri.....  | 343-346            | rice.....   | 295-296            |
| Cocheneur, William S. (paper): Germ-Free                  |                    | timothy hay.....  | 286                |
| Filtrates as Antigens in the Complement-                  |                    | wheat.....  | 291                |
| Fixation Test.....  | 513-515            | physical and chemical basis.....                              | 300-311            |
| Crana, blue. See <i>Boutonia gracilis</i> .               |                    | Hooded barley, limitations.....                               | 431-472            |
| Grapefruit—   |                    | <i>Hordeum</i> —  |                    |
| infection of roots by <i>Pseudomonas citri</i> ...        | 221-222            | <i>distichon palmella</i> —                                   |                    |
| See <i>Citrus maxilla</i> .                               |                    | cross with <i>H. vulgare pallidum</i> .....                   | 575-592            |
| Grass—  |                    | <i>aeosorum</i> , intermediate.....                           | 576                |
| 'along-alang. See <i>Imperata</i> .....                   |                    | intermedium haxtoni, in barley crosses.....                   | 575-592            |
| buffalo. See <i>Bubilla</i> .....                         |                    | <i>jubatum</i> , host of <i>Puccinia graminis tritici</i> ... | 270                |
| Greensand, effect of manure-sulphur on                    |                    | <i>vulgare</i> —  |                    |
| availability of potassium.....                            | 239-256            | host of <i>Puccinia glumarum</i> .....                        | 258                |
| <i>Gymnocris interstitialis</i> —                         |                    | <i>pallidum</i> , cross with <i>H. distichon palmella</i>     | 575-592            |
| color of spores.....                                      | 502-504            | Humidity, effect on strength and elasticity of                |                    |
| germination.....  | 502-503            | wool fiber.....   | 55-62              |
| morphology of aeciospores.....                            | 504-507            |   |                    |

|  | Page    |   | Page               |
|--|---------|---|--------------------|
| Hungerford, Charles W. (paper): Rust in Seed Wheat and Its Relation to Seedling Infection.....   | 257-278 | Line-Selection Work with Potatoes (paper). 548-573  |                    |
| Hybrid, teosinte-maize.....  | 1-38    | "Loco weed." See <i>Oxytropis lamberti</i> .  |                    |
| Hybrids, "false," susceptibility to <i>Pseudomonas citri</i> .....   | 359     | Magnesium—  |                    |
| Hydroxide, sodium, effect on germination and growth.....   | 74-96   | oxid in greensand.....  | 344                |
| <i>Imperata</i> —  |         | sulphate, effect on germination and growth.....   | 74-96              |
| <i>cylindracea</i> , resistance to <i>Sclerospora philippinensis</i> .....   | 104     | Magness, J. R. (paper): Investigations in the Ripening and Storage of Bartlett Pears..  | 473-500            |
| sp., resistance to <i>Sclerospora javanica</i> .....   | 105     | Maize—  |                    |
| Indol production by <i>Bacterium coronafaciens</i> .....   | 151     | hybrid with teosinte.....   | 1-38               |
| Influence of Fermentation on the Starch Content of Experimental Silage (paper).....  | 173-179 | See <i>Zea mays</i> .   |                    |
| Insect transmission of—  |         | Malcomson, A. W., and Ashby, R. C. (paper): Variation of Individual Pigs in Economy of Gain.....  | 235-234            |
| corn mosaic.....   | 520-521 | Malic acid. See Acid, malic.  |                    |
| sugar-cane mosaic.....   | 131-138 | Manchuria barley, effect of removing awns.....  | 439-453            |
| Intermediate, fixed, in barley crosses.....  | 575-592 | Manure-sulphur composts, effect on availability of potassium of greensand.....  | 239-256            |
| Investigations in the Ripening and Storage of Bartlett Pears (paper).....  | 473-500 | McCall, A. G., and Smith, A. M. (paper): Effect of Manure-Sulphur Composts upon the Availability of the Potassium of Greensand.....     | 239-256            |
| Irish potato. See <i>Solanum tuberosum</i> .   |         | McCool, M. M., and Millar, C. E. (paper): Effect of Calcium Sulphate on the Solubility of Soils.....                                    | 47-54              |
| Johann, Helen, and Dickson, James G. (paper): Production of Conidia in <i>Gibberella saubinetii</i> .....  | 235-237 | Mellvaine, T. C., and Salter, Robert M. (paper): Effect of Reaction of Solution on Germination of Seeds and on Growth of Seedlings..... | 73-96              |
| Juniper berries, effect on milk and fat production.....  | 125-130 | Mealy bug, sugar-cane. See <i>Pseudococcus boninensis</i> .   |                    |
| Kempton, J. H., and Collins, G. N. (paper): A Teosinte-Maize Hybrid.....   | 1-38    | <i>Melia azedarach</i> , immunity to <i>Pseudomonas citri</i> .....   | 342                |
| Kernels, barley—   |         | <i>Melicope triphylla</i> , susceptibility to <i>Pseudomonas citri</i> .....  | 345, 346           |
| daily development.....   | 393-430 | <i>Microcitrus</i> —  |                    |
| development in normal and clipped spikes.....  | 431-472 | <i>australasica</i> —   |                    |
| <i>Koeleria cristata</i> on northern Great Plains.....   | 65-72   | susceptibility to <i>Pseudomonas citri</i> .....  | 344, 345, 347, 348 |
| Kumquat. See <i>Fortunella</i> spp.  |         | var. <i>sanguinea</i> , susceptibility to <i>Pseudomonas citri</i> .....  | 344, 345, 347      |
| Kunkel, L. O. (paper): Further Data on the Orange-Rusts of Rubus.....  | 501-512 | <i>australis</i> , susceptibility to <i>Pseudomonas citri</i> .....   | 345, 347, 348      |
| Kurtzwell, Carl, et al. (paper): Genetics of Rust Resistance in Crosses of Varieties of Triticum vulgare with Varieties of T. durum and T. dicoccum..... | 523-552 | <i>Garroveyi</i> , susceptibility to <i>Pseudomonas citri</i> .....   | 344, 345, 347      |
| <i>Laciniaria punctata</i> on northern Great Plains.....   | 65-72   | Mildew, Philippine downy. See <i>Sclerospora philippinensis</i> .   |                    |
| <i>Lactuca sparsifolia</i> on northern Great Plains.....   | 65-72   | Milk production, effect of drugs.....   | 123-130            |
| <i>Lansium domesticum</i> , susceptibility to <i>Pseudomonas citri</i> .....   | 341     | Millar, C. E., and McCool, M. M. (paper): Effect of Calcium Sulphate on the Solubility of Soils.....                                    | 47-54              |
| <i>Lapinotarsa decemlineata</i> , failure to transmit potato mosaic.....   | 349     | Moisture—   |                    |
| Lavanginae, susceptibility to <i>Pseudomonas citri</i> .....   | 343     | relations of <i>Bacterium coronafaciens</i> .....   | 151                |
| Leafhopper, sharp-headed grain. See <i>Draculacephala molipes</i> .  |         | soil, influence on persistence of <i>Pseudomonas citri</i> .....  | 214-217            |
| Lee, H. Atherton (paper): Behavior of the Citrus Canker Organism in the Soil.....  | 189-206 | Mosaic Disease of Corn (paper).....   | 517-522            |
| Lime—  |         | Mosaic—   |                    |
| air-slaked, effect on milk and fat production.....   | 125-130 | Irish potato—   |                    |
| inefficacy in preventing seed injury from formalin.....  | 363-362 | transmission by—  |                    |
| milk of, effect on germination of wheat.....   | 379     | grating.....  | 319-320            |
| Lime. See <i>Citrus aurantiifolia</i> .  |         | insects.....  | 326-332            |
| Limeo, susceptibility to <i>Pseudomonas citri</i> .....  | 356     | plant juice.....  | 320-326            |
| Limequat, susceptibility to <i>Pseudomonas citri</i> .....   | 356     | soil harboring.....   | 335-337            |
| <i>Limonia glutinosa</i> . Syn. <i>Chaetochytrium glutinosum</i> .   |         | sugar-cane, artificial and insect transmission.....   | 131-138            |
|  |         | Moquette, G. F. (paper): Banana Root-Borer.....   | 39-46              |

|   | Page    |  | Page               |
|---|---------|--|--------------------|
| <i>Muhlenbergia cuspidata</i> on northern Great Plains.....   | 65-72   | Physostigmine—   |                    |
| <i>Murrata esotica</i> . Syn. <i>Chalcas esotica</i> .....  | 39-46   | effect on milk and fat production.....   | 124                |
| <i>Musa</i> spp., hosts of <i>Cosmopolites sordidus</i> .....   | 39-46   | sulphate, effect on milk and fat production.....   | 125-130            |
| Navel orange. See <i>Citrus sinensis</i> .  |         | Pigs, variation in economy of gain.....  | 225-234            |
| Nitrate—  |         | Pilocarpine, effect on milk and fat production.....  | 124                |
| potassium, effect on germination and growth.....  | 74-96   | Pituitarian, effect on milk and fat production.....  | 124                |
| sodium, effect on germination and growth.....   | 74-96   | <i>Polygala alba</i> on northern Great Plains.....   | 65-72              |
| Nitrogen content—   |         | <i>Poncirus trifoliata</i> , susceptibility to <i>Pseudomonas citri</i> .....  | 343; 345; 347; 348 |
| change during development of barley kernels.....  | 418-428 | Potassium—   |                    |
| of wheat, effect of freezing.....   | 183-286 | effect of manure-sulphur composts on availability in greensand.....  | 239-256            |
| of kernels from normal and clipped barley spikes.....   | 458-460 | nitrate, effect on germination and growth.....   | 74-96              |
| Nonnutaceous plants, susceptibility to <i>Pseudomonas citri</i> .....   | 342     | sulphate, effect on germination and growth.....  | 74-96              |
| Nux vomica, effect on milk and fat production.....  | 124     | Potato, Irish. See <i>Solanum tuberosum</i> .  |                    |
| Oats. See <i>Avena sativa</i> .....   |         | Practical Universality of Field Heterogeneity as a Factor Influencing Plot Yields (paper).....   | 279-314            |
| Occurrence of the Fixed Intermediate, <i>Hordeum intermedium</i> haxtoni, in Crosses between <i>H. vulgare pallidum</i> and <i>H. distichon palmella</i> (paper).....                           | 573-592 | Presoak Method of Seed Treatment: A Means of Preventing Seed Injury Due to Chemical Disinfectants and of Increasing Germicidal Efficiency (paper)..... | 353-392            |
| Oil, castor, effect on milk and fat production.....   | 124     | Production of <i>Candida</i> in <i>Gibberella saubinetii</i> (paper).....  | 235-237            |
| Orange, navel. See <i>Citrus sinensis</i> .   |         | <i>Pseudococcus dominiensis</i> , failure to carry sugarcane mosaic.....   | 136                |
| Orange, susceptibility to <i>Pseudomonas citri</i> .....  | 356     | <i>Pseudomonas</i> —   |                    |
| Orangequat, susceptibility to <i>Pseudomonas citri</i> .....  | 357     | <i>ovata</i> , causal organism of blight of oats.....  | 167                |
| Orange-rusts of <i>Rubus</i> . See <i>Gymnocris interstitialis</i> .  |         | <i>citri</i> —   |                    |
| Oxid—   |         | behavior in soil.....  | 189-206            |
| aluminum, in greensand.....   | 244     | decline in the soil.....   | 207-223            |
| calcium, in greensand.....  | 244     | relative susceptibility of species of Citrus.....  | 339-362            |
| ferrie, in greensand.....   | 244     | <i>Psoralea argophylla</i> on northern Great Plains.....   | 65-72              |
| magnesium, in greensand.....  | 244     | Puccinia—  |                    |
| <i>Oxytropis lamberti</i> , on northern Great Plains.....   | 65-72   | <i>coronata</i> —  |                    |
| <i>Panicum dichotomiflorum</i> , susceptibility to sugarcane mosaic.....  | 134     | <i>agropyri</i> , pathogenic on <i>Agropyron repens</i> .....  | 258                |
| <i>Paramomya longipedunculata</i> , susceptibility to <i>Pseudomonas citri</i> .....  | 345     | pathogenic on oats.....  | 257; 265           |
| Parker, John H., et al. (paper): Genetics of Rust Resistance in Crosses of Varieties of <i>Triticum vulgare</i> with Varieties of <i>T. durum</i> and <i>T. dicoccum</i> .....                  | 523-540 | <i>glumarum</i> —  |                    |
| Pears, Bartlett, ripening and storage.....  | 473-500 | on caryopses of Gramineae.....   | 258; 265           |
| Peltier, George L., and Frederick, William J. (paper): Relative Susceptibility to Citrus-Canker of Different Species and Hybrids of the Genus <i>Citrus</i> , Including the Wild Relatives..... | 339-362 | resistance of wheats.....  | 526                |
| Pentoxid, phosphorus, in greensand.....   | 244     | <i>graminis</i> —  |                    |
| <i>Peronospora meyeris</i> . Syn. <i>Sclerospora javanica</i> .   |         | in Australia.....  | 257                |
| <i>Petalostemon</i> —   |         | resistance of wheat crosses.....   | 523-542            |
| <i>candidum</i> on northern Great Plains.....   | 65-72   | <i>tritici</i> —   |                    |
| <i>purpureum</i> on northern Great Plains.....  | 65-72   | effect on germination.....   | 263                |
| Philippine Downy Mildew of Maize (paper).....   | 97-122  | effect on growth of seedlings.....   | 263-275            |
| Phosphate—  |         | parasitic on <i>Hordeum jubatum</i> .....  | 270                |
| calcium, effect on solubility of soils.....   | 50-51   | resistance of wheat crosses.....   | 524-542            |
| dipotassium, effect on germination and growth.....  | 74-96   | <i>malvacearum</i> , pathogenic on hollyhock seeds.....  | 259                |
| Phosphoric acid. See Acid, phosphoric.  |         | <i>montanensis</i> , pathogenic on <i>Elymus canadensis</i> .....  | 257                |
| Phosphorus pentoxid in greensand.....   | 244     | <i>simplex</i> , pathogenic on barley kernels.....   | 258                |
|   |         | <i>triticea</i> , parasitic on wheat.....  | 265                |
|   |         | Pumelo. See <i>Citrus maxima</i> .   |                    |
|   |         | Ragi. See <i>Eleusine coracana</i> .   |                    |
|   |         | Raspberry, black, host of <i>Gymnocris interstitialis</i> .....  | 501-507            |
|   |         | <i>Ratibida columnaris</i> on northern Great Plains.....   | 65-72              |
|   |         | Relative Susceptibility to Citrus Canker of Different Species and Hybrids of the Genus Citrus, Including the Wild Relatives (paper).....               | 339-362            |

|   | Page    |   | Page             |
|---|---------|---|------------------|
| <i>Rhizobium leguminosarum</i> , critical soil reaction.....  | 85      | Seed treatment, presoak method.....   | 363-392          |
| Root-borer, banana. See <i>Cosmopolites sordidus</i> .  |         | Seeds, germination, effect of reaction of solution.....   | 73-96            |
| <i>Rotboellia exaltata</i> , resistance to <i>Sclerospora philippinensis</i> .....  | 104     | <i>Severinia buxifolia</i> , immunity to <i>Pseudomonas citri</i> .....   | 343-345, 347     |
| <i>Rubus</i> —  |         | Siamor, susceptibility to <i>Pseudomonas citri</i> .....  | 357              |
| <i>alleghaniensis</i> , host of <i>Gymnoconia interstitialis</i> .....  | 506     | Siamor, susceptibility to <i>Pseudomonas citri</i> .....  | 357              |
| <i>americanus</i> , host of <i>Gymnoconia interstitialis</i> .....  | 505-506 | Silage, influence of fermentation on starch content.....  | 173-179          |
| <i>canadensis</i> , host of <i>Gymnoconia interstitialis</i> .....  | 506     | Smith, A. M., and McCall, A. G. (paper): Effect of Manure-Sulphur Composts upon the Availability of the Potassium of Greensand..... | 839-256          |
| <i>cuneifolius</i> , host of <i>Gymnoconia interstitialis</i> .....   | 505-506 | Sodium—   |                  |
| <i>hispidus</i> , host of <i>Gymnoconia interstitialis</i> .....  | 505-506 | bicarbonate, effect on milk and fat production.....   | 125-130          |
| <i>nigrobaccus</i> , host of <i>Gymnoconia interstitialis</i> .....   | 505-506 | hydroxid, effect on germination and growth.....   | 74-96            |
| <i>parviflorus</i> , host of <i>Gymnoconia interstitialis</i> .....   | 505-506 | nitrate, effect on germination and growth.....  | 74-96            |
| <i>procumbens</i> , host of <i>Gymnoconia interstitialis</i> .....  | 505-506 | Soil—   |                  |
| <i>striatus</i> , host of <i>Gymnoconia interstitialis</i> .....  | 506     | effect of calcium sulphate on solubility.....   | 47-54            |
| <i>triflorus</i> , host of <i>Gymnoconia interstitialis</i> .....   | 506     | in vicinity of Northern Great Plains Field Station.....   | 61-64            |
| <i>ursinus</i> , host of <i>Gymnoconia interstitialis</i> .....   | 505-506 | <i>Pseudomonas citri</i> in.....  | 189-206, 207-223 |
| <i>spp.</i> , hosts of <i>Gymnoconia interstitialis</i> .....   | 505-512 | <i>Solanum tuberosum</i> —  |                  |
| Rust in Seed Wheat and Its Relation to Seedling Infection (paper).....  | 257-278 | host of mosaic disease.....   | 315-338          |
| Rust resistance in wheat crosses.....   | 523-542 | line-selection work.....  | 543-573          |
| Rutaceous plants, susceptibility to <i>Pseudomonas citri</i> .....  | 341     | <i>Solidago pulcherrima</i> on northern Great Plains.....   | 65-72            |
| Rye, wild. See <i>Elymus canadensis</i> .   |         | Solubility of soils, effect of calcium sulphate.....  | 47-54            |
| <i>Saccharum</i> —  |         | <i>Sorghum</i> . See <i>Andropogon sorghum</i> .  |                  |
| <i>officinarium</i> , resistance to <i>Sclerospora philippinensis</i> .....   | 104     | Species, new.....   | 97-122, 123-172  |
| <i>spontaneum</i> , host of <i>Sclerospora</i> sp.....  | 104     | Starch—   |                  |
| Salter, Robert M., and Melville, T. C. (paper): Effect of Reaction of Solution on Germination of Seeds and on Growth of Seedlings.....  | 73-96   | in experimental silage, influence of fermentation.....  | 173-179          |
| Salt, common, effect on milk and fat production.....  | 124     | in frozen wheat.....  | 187              |
| Salts, epsom, effect on milk and fat production.....  | 124     | in silage.....  | 175-178          |
| Sarvis, J. T. (paper): Composition and Density of the Native Vegetation in the Vicinity of the Northern Great Plains Field Station..... | 62-72   | Stemrust. See <i>Puccinia graminis</i> .  |                  |
| Satsuma. See <i>Citrus nobilis</i> var. <i>unshiu</i> .   |         | Sterility in wheat crosses.....   | 597-532          |
| Satsumelo, susceptibility to <i>Pseudomonas citri</i> .....   | 357     | <i>Stipa</i> —  |                  |
| Schultz, E. S., and Folsom, Donald (paper): Transmission of the Mosaic Disease of Irish Potatoes.....                                   | 315-338 | <i>comata</i> on northern Great Plains.....   | 65-72            |
| <i>Sclerospora</i> —  |         | <i>spartea</i> on northern Great Plains.....  | 65-72            |
| <i>graminicola</i> —  |         | <i>viridula</i> on northern Great Plains.....   | 65-72            |
| dissimilarity of <i>Sclerospora philippinensis</i> var. <i>andropogonis-sorgho</i> , classification.....                                | 105     | Storage, effect on ripening of Bartlett pears.....  | 473-500          |
| <i>japonica</i> , hosts.....  | 105     | Striperust. See <i>Puccinia glumarum</i> .  |                  |
| <i>maydis</i> , suspected occurrence on teosinte.....   | 105     | Sucrose in frozen wheat.....  | 187              |
| <i>philippinensis</i> , n. sp.—   |         | Sugar-cane mosaic, artificial and insect transmission.....  | 131-158          |
| causal organism.....  | 105-122 | Sugars—   |                  |
| hosts.....  | 103-105 | in Bartlett pears.....  | 480-499          |
| <i>sacchari</i> , pathogenicity on sugar cane, maize, and teosinte.....   | 105     | in frozen wheat.....  | 187              |
| <i>Sclerostylis Hindii</i> . Syn. <i>Fortunella Hindii</i> .  |         | in silage.....  | 174-177          |

|  | Page    |  | Page    |
|--|---------|--|---------|
| Sulphid of antimony, black, effect on milk and fat production.....                             | 125-130 | <i>Triticum</i> —Continued.....  |         |
| Sulphur, effect on milk and fat production. 125-130  |         | <i>sativum</i> , crosses.....  | 524     |
| Sulphur-manure composts, effect on availability of potassium of greensand.....                 | 239-250 | <i>spelta</i> , crosses.....   | 524     |
| Sunlight, effect on <i>Bacterium coronafaciens</i> .....                                       | 153     | <i>turgidum</i> , crosses.....   | 524     |
| <i>Syntherisma sanguinalis</i> , susceptibility to sugar-cane mosaic.....                      | 134     | <i>vulgare</i> —   |         |
| Tangelo, susceptibility to <i>Pseudomonas citri</i> .....                                      | 357     | host of <i>Puccinia glumarum</i> .....   | 298     |
| Temperature—   |         | rust resistance in crosses.....  | 523-542 |
| influence on—  |         | <i>Uromyces euphorbiae</i> , pathogenic on <i>Euphorbia deltoidea</i> .....  | 259     |
| dry weight of Bartlett pears in storage. 494-495   |         | Variation of Individual Pigs in Economy of Gain (paper).....   | 225-234 |
| germination of <i>Gymnoconia interstitialis</i> . 502-503                                      |         | Vibrona septique, separation by germ-free filtrates.....   | 513     |
| relation to—   |         | <i>Vicia sparsifolia</i> on northern Great Plains....  | 69-72   |
| <i>Bacterium coronafaciens</i> .....   | 151     | Water—   |         |
| rust infection.....  | 269-270 | effect on production of carbon dioxide by calcium sulphate in soil.....  | 57-58   |
| soil, effect on persistence of <i>Pseudomonas citri</i> .....                                  | 213-214 | in barley kernels—   |         |
| Teosinte-Maize Hybrid, A (paper).....  | 1-38    | change during development of barley kernels.....   | 412-428 |
| Teosinte. See <i>Euchlaena</i> —   |         | from normal and clipped barley spikes. 457-469   |         |
| <i>luxurians</i> .   |         | Weed, "loco." See <i>Oxytropis lamberti</i> .  |         |
| <i>mexicana</i> .  |         | Weston, William H., jr. (paper): Philippine Downy of Mildew of Maize.....  | 97-122  |
| <i>Tetranychus binucleolus</i> , transmission of sugar-cane mosaic.....                        | 733     | Wheat, relation of rust to seedling infection. 257-278   |         |
| Thomas, Merton G., and Hays, Frank A. (paper): Effect of Drugs on Milk and Fat Production..... | 123-130 | Whipple, O. B. (paper): Line-Selection Work with Potatoes.....   | 543-573 |
| <i>Toddalia asiatica</i> , susceptibility to <i>Pseudomonas citri</i> .....                    | 345-346 | Wild rye. See <i>Elymus canadensis</i> .   |         |
| Transmission of the Mosaic Disease of Irish Potatoes (paper).....                              | 315-338 | Wool fiber, influence of humidity on strength and elasticity.....  | 55-62   |
| <i>Triphasia</i> —   |         | <i>Xanthoxylum</i> —   |         |
| <i>glauca</i> . Syn. <i>Eremocitrus glauca</i> .   |         | <i>clara-hercules</i> , susceptibility to <i>Pseudomonas citri</i> .....   | 346     |
| <i>trifolia</i> , immunity to <i>Pseudomonas citri</i> .....                                   | 345-347 | <i>saqara</i> , susceptibility to <i>Pseudomonas citri</i> .....   | 346     |
| <i>Triticum</i> —  |         | <i>rheta</i> , immunity to <i>Pseudomonas citri</i> .....  | 345     |
| <i>dicoccoides</i> , discovery.....  | 525     | sp., immunity to <i>Pseudomonas citri</i> .....  | 347     |
| rust resistance in crosses with <i>T. vulgare</i> 523-542                                      |         | Yoder, Lester, and Dox, Arthur W. (paper): Influence of Fermentation on the Starch Content of Experimental Silage..... | 173-179 |
| <i>durum</i> —   |         | <i>Zea</i> —   |         |
| crosses.....   | 524     | <i>mays</i> , host of—   |         |
| rust resistance in crosses with <i>T. vulgare</i> 523-542                                      |         | mosaic disease.....  | 517-522 |
| <i>polonicum</i> , crosses.....  | 524     | Philippine downy mildew.....   | 97-122  |
|  |         | <i>ramosa</i> , growth of branches.....  | 25      |















